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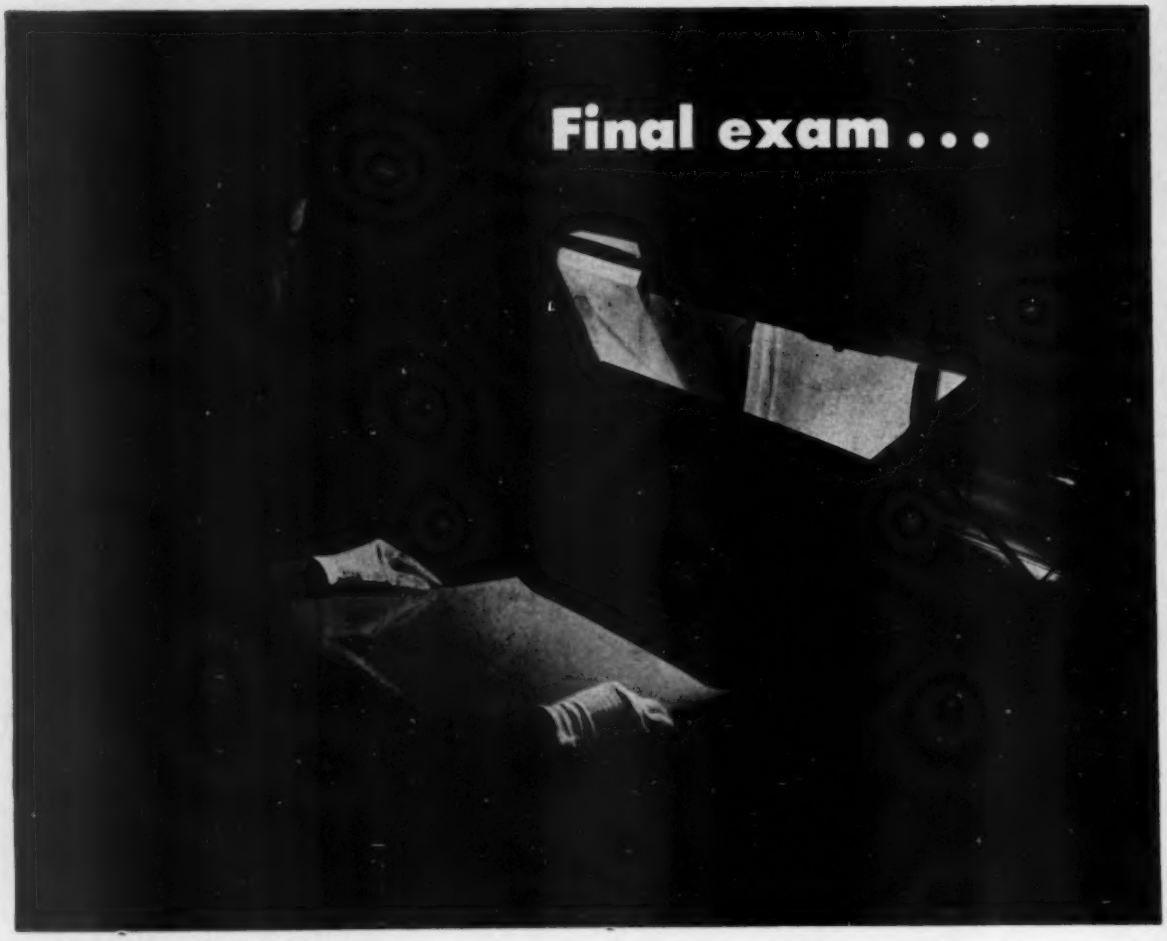

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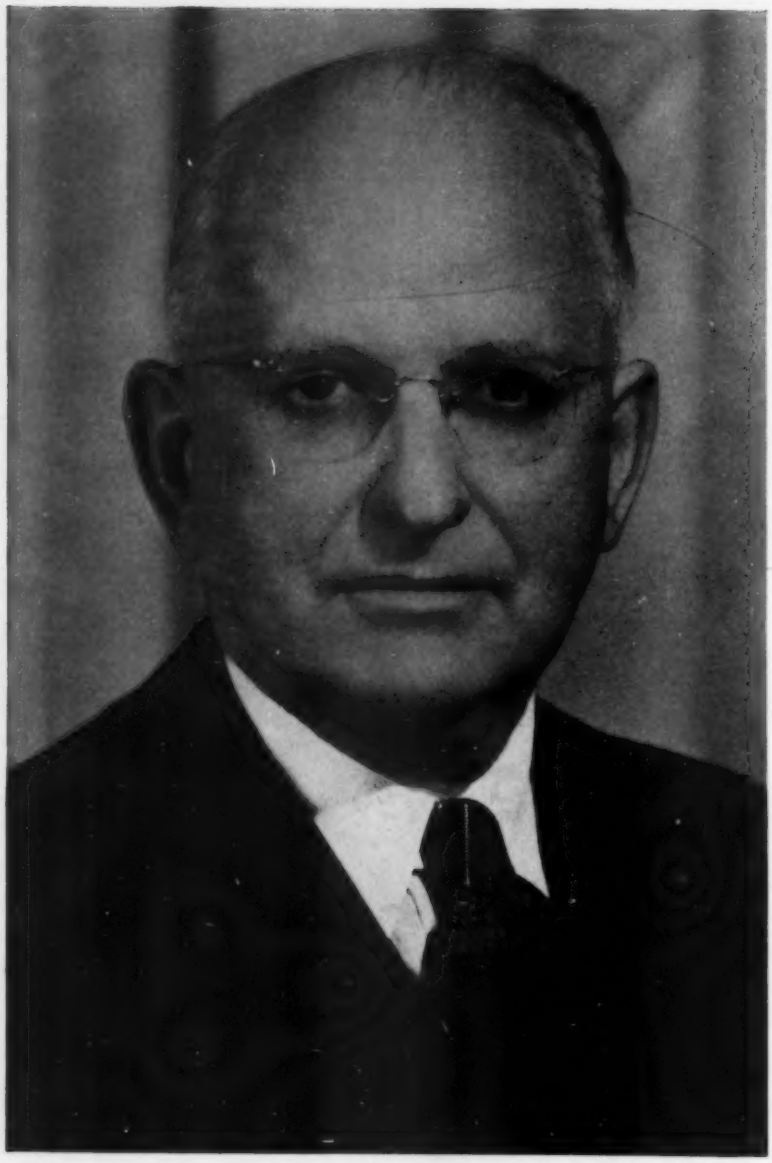

LYELL C. KINNEY
President of the American Roentgen Ray Society 1944–1945

THE AMERICAN JOURNAL OF ROENTGENOLOGY AND RADIUM THERAPY

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CONGENITAL ABSENCE OF THE LUNG (AGENESIS) AND OTHER ANOMALIES OF THE TRACHEOBRONCHIAL TREE

By CHARLES F. FERGUSON, M.D.,* *and* EDWARD B. D. NEUHAUSER, M.D.†
BOSTON, MASSACHUSETTS

SUCH developmental abnormalities as agenesis of an entire lung have been encountered so rarely that only about 50 cases have been recorded in the medical literature. Van Loon and Diamond,[18] from Jackson's Bronchoscopic Clinic in Philadelphia, in 1941 reported what was apparently the third case of agenesis of the lung diagnosed before death, and stated that until that time there were on record only 40 genuine cases of this congenital anomaly. In 1941, Geissler[6] described a postmortem examination of another similar case, and in June, 1942, Castellanos and Pereiras[3] from Cuba reported 3 additional cases, together with a review of the literature.

At The Children's Hospital in Boston during the past six years we have encountered 5 cases of agenesis of the lung, all 5 of which have been diagnosed during life by bronchoscopic examination followed by lipiodol roentgenograms of the tracheobronchial tree. Of these 5 cases, 4 are still living apparently normal lives, while autopsy confirmed the clinical diagnosis of the fifth.

Munchmeyer[14] in 1885 is credited with having made the first diagnosis of unilateral pulmonary agenesis on the basis of a physical examination, subsequently verified by autopsy. This condition was found in a two year old boy who had died of pneumonia shortly after the clinical diagnosis of agenesis had been made. In 1893, Schmit[15] described a case of bilateral agenesis of the lungs in a fetus of eight months' gestation, whose trachea had not as yet separated from the esophageal wall, but whose larynx was well developed. There were no pleural membranes, and no vestiges of pulmonary veins. The pulmonary arteries connected with the descending aorta.

It was not until 1928 that Gilkey[7] reported the second case of agenesis of the lung diagnosed during life. The patient of Van Loon and Diamond[18] was apparently the third case clinically diagnosed. For this reason, 5 cases recognized during life at one clinic, together with their respective bronchograms, should prove of interest. Furthermore, the report of these cases should stimulate more general investigation of obscure lung conditions by recommended methods of bronchoscopy and lipiodol in-

* Associate Visiting Otolaryngologist and Acting Head of Department, The Children's Hospital, Boston; Assistant in Otology, Harvard Medical School.
† Roentgenologist, The Children's Hospital, Boston; Instructor in Roentgenology, Harvard Medical School.

jection. Hurwitz and Stevens[10] in 1937 published a complete tabulation of the 34 cases recorded until that time. According to this report and the literature in general, the sex ratio favors the males in a proportion of about three to two. The anomaly has been found to occur somewhat more commonly on the left side than on the right, in a proportion of nearly two to one. In our series of 5 cases, there was agenesis of the left lung in 3 patients and of the right lung in 2 patients. Of these, however, 3 were females and 2 were males. It is impossible to offer any estimate as to the general incidence of this condition, inasmuch as the total number of reported cases is so small, and the literature is composed almost entirely of individual case reports. Killingsworth and Hibbs[11] reported that of the 37 authentic cases in the literature until 1939, twenty-four had been found in children under twelve years of age. Of these, 3 were stillborn, 5 were infants under one week, 13 were under six months of age, 2 under three years, 1 was eight years and 1 was twelve years of age. In 24 of the 37 cases, the left lung was involved. In those cases in which the sex was reported, there were 20 males and 13 females.

The cause of this condition is unknown, but various theories have been propounded in an attempt to offer some explanation for the developmental defect. Meckel and Fleischmann[13] have suggested a cause on a phylogenetic basis, and regard the condition as an atavistic reversion to a reptilian stage. Klebs[12] explains an agenesis of the right lung as the result of excessive tension on the amnion, produced as the embryo normally rotates to the left, thereby preventing proper development of the right lung. This, however, leaves no room for an explanation of the left-sided defect, and the left side is the one more commonly found to be aplastic. Eppinger's[5] theory deals with enlargement and displacement of the thymus gland, thereby causing undue pressure on the developing bronchopulmonary system. Gruenfeld and Gray[8] feel that the phylogenetic newness of the lung, plus the enormous growth the lung must undergo before its functional form is achieved, has some bearing on the development of abnormalities. Tichomiroff[17] believed that hydrops fetalis or some early intrauterine infection might be the cause of the defect. One of the most plausible theories is that of Schwalbe,[16] who postulates that the condition is due to a developmental error of endogenous origin; that is, it is the result of an inherently faulty germ-plasm. According to Schwalbe, there is a primary defect in the pulmonary vascular, as well as in the respiratory system. The pulmonary vessels on the affected side are usually absent and a single pulmonary artery often supplies the hypertrophied lung. The aortic vessels may arise from a common trunk. This theory of a developmental error of endogenous origin seems most logical, inasmuch as other abnormalities of development are often associated in the same patient. It is surprising to note the great number of cases in the literature which have shown coincidental anomalies. These anomalies have included such local defects as a narrowed trachea, extra cartilaginous rings, supernumerary bronchi of the normal lung, absence of the pleura on the affected side, tracheo-eosphageal fistula, esophageal stenosis and synostosis of various ribs. In addition, other more distant congenital abnormalities have been reported; such as, absent diaphragm on the affected side; atresia of the anus; hypoplasia of the face; absence of one ovary and tube; dermoid of the eye; agenesis of the spleen, kidney and ureter; accessory or hypertrophied thymus; exencephaly; absent vagus nerve and various bone and cardiovascular anomalies. Each of our 5 cases had some other anomaly, such as a harelip and cleft palate, an absent wrist and hand on the same side as the aplastic lung, an anomaly of the external ear and other minor congenital defects.

To understand this condition more clearly, it is important to look briefly at the embryology of the bronchopulmonary system. According to Arey,[1] "A groove-like evagination occurs on the ventral surface of

the esophagus in the 3 mm. human embryo. From the enlarged posterior ends of the groove, two small lung buds grow out. Later in the development, the predestined anlage of the trachea and esophagus become separated by a constriction, interrupted at the cephalic end by the larynx which can be seen in the embryo at the end of the fifth week. Muscle fibers and cartilaginous rings differentiate from the surrounding mesenchyme by the end of the seventh week. In a later development of the lung buds, hollow evaginations grow out into the envelope of connective tissue, enlarge rapidly and branch to produce the tree-like tubular system. On the fine terminal tubules arise small out-growths which constitute the alveoli." Therefore, complete absence of the lung, with no lung bud or main stem bronchus whatever, indicates a developmental defect which has occurred very early in fetal life. Those cases which occur in Groups II or III, to be described in the next paragraph, with either a rudimentary bronchus or a fairly well developed bronchus with no lung tissue, are due to failure of development occurring at a somewhat later embryonic stage.

Schneider[16] has divided the cases of pulmonary agenesis into three distinct anatomic classifications, depending on the age at which the developmental defect occurred. I. True aplasia—cases in which there is no trace of a lung, bronchus or vascular supply to the affected side. II. Cases in which there is a tiny out-pocketing of the trachea; that is, a primordial bronchial bud, but no lung tissue. III. Extreme hypoplasia—cases in which the bronchus is fully developed, but reduced in size and ending in a fleshy structure without lobes which lies in the mediastinum. The great majority of cases reported fall in the first category; namely, a true aplasia. However, only 2 of our 5 cases fell in this group, while the other 3 showed (on the lipiodol bronchograms) rudimentary bronchial buds, but no evidence of lung tissue. The third group of cases, that is those of hypoplasia of the lung but with a fairly well formed bronchus, is apparently quite small and, up to 1934, only 5 such cases had been reported (Dyson[4]).

Symptoms produced by agenesis of the lung may be very variable, or may be entirely lacking. In fact, some of our cases were suspected only during physical examinations in otherwise essentially normal children. One may possibly encounter in such cases a diminished respiratory excursion on the affected side; a slight flattening of the thorax with possible scoliosis (although usually the chest is symmetrical); dullness or flatness to percussion, unless the compensatory emphysema of the other lung confuses the picture; absent breath sounds; or bronchial breathing. In practically every case, the potentially vacant space in the chest is filled with displaced heart, thymus and other mediastinal contents; and, on occasions, there may be clinical evidence of fluid in the chest. Dyspnea, stridor and even cyanosis have been reported.

At postmortem examination, the pleura may be defective or completely absent. The affected side of the chest cavity may be filled with fluid, but in most cases only with the displaced mediastinal structures. If the bronchus is present, it is usually short and rudimentary. If no bronchus is present, the trachea and single bronchus may be perfectly uniform in diameter throughout, with no evidence of division and no narrowing. Two of our cases showed a "trachea" or "bronchus" which connected the larynx with the hilum of the normal lung, and which did not vary at all in diameter. Here there was no evidence of a bronchial bud. The trachea, however, may be narrowed and the cartilaginous rings may be increased in number. The pulmonary vessels are usually absent, and a single pulmonary artery often supplies the hypertrophied lung. The aortic vessels may arise from a common trunk and the venous return of the normal lung may reach the left auricle by way of one or more vessels or empty directly into the azygos vein. The functioning lung is usually hypertrophied and emphysematous and may show abnor-

Fig. 1. (R. R.) The right upper lobe bronchus emerges from the trachea above the bifurcation. There is marked irregular stenosis of the trachea between the bifurcation and the emergence of the upper lobe bronchus.

mal lobulation. Possibly there may also be pneumonia and in one case bronchiectasis was reported. Very often, cases are erroneously diagnosed as pneumonia, massive atelectasis, foreign body in the bronchus, hydrothorax, diaphragmatic hernia or diaphragmatic paralysis. However, from the roentgenograms alone the condition may often be suspected. There is generally a dense, homogeneous shadow on the affected side, with displacement of the heart and mediastinum to that side and with elevation of the diaphragm and narrowing of the intercostal spaces. There may be some abnormality of the thoracic cage or even some scoliosis.

As Hurwitz and Stevens[10] suggested in 1937, bronchoscopy is the only rational and final method for accurate clinical diagnosis. These authors claim priority for advocating this procedure in such cases. Lipiodol injection at the time of bronchoscopy should solve the problem. However, the seven weeks old baby girl reported by Hurwitz and Stevens died two days after its second bronchoscopy and no diagnosis was made until the time of postmortem examination. In this case, no lipiodol was injected since the baby was in poor general condition. The practice of thoracic paracentesis as a diagnostic measure is mentioned only to be condemned, although in the past it has been too frequently employed. In the hands of one experienced in the use of the bronchoscope in infants and children and in the technique of lipiodol injection, the procedure should prove neither difficult for the operator nor dangerous to the patient.

It is quite obvious that the prognosis in congenital absence of a lung should always be guarded. In the first place, there may be other unknown congenital anomalies, which may of themselves prove serious. In addition, any otherwise insignificant involvement of the only existing lung, whether it be from infection, foreign body or trauma, may cause sudden fatality. However, Killingsworth and Hibbs[11] report that 11 cases in the literature lived beyond nineteen years of age, while 3 were fifty-eight, sixty-

Fig. 2. (R. R.) Slightly oblique view to show the marked stenosis of the trachea.

five and seventy-two years of age respectively at the time of death. All of these patients died of causes unrelated to the pulmonary agenesis. Heerup[9] in 1927 reported the case of a seventy-two year old woman who died of cerebral hemorrhage before the absence of the lung was discovered. Therefore, the condition may be compatible with longevity.

As lipiodol roentgenograms become more universally employed in the diagnostic study of unusual lung conditions, there will obviously be an increase in the number of reported cases, not only of agenesis, but also of various other bronchopulmonary anomalies. In patients who have had pneumonia recur several times in the same lobe, a congenital malformation of that bronchus must be suspected. One such patient (R. R.) (Fig. 1 and 2) showed a narrow angulated bronchus to the right upper lobe arising above the tracheal bifurcation. An area of localized atelectasis or emphysema also demands investigation by bronchoscopic methods, not only for the relief of the local defect, but also for the determination of its cause. One of our patients (G. B.) (Fig. 3 and 4) was studied because of persistent

Fig. 3. (G. B.) Atelectasis of the right middle and lower lobes, with a marked shift of the heart and mediastinum to the right, and elevation of the right dome of the diaphragm.

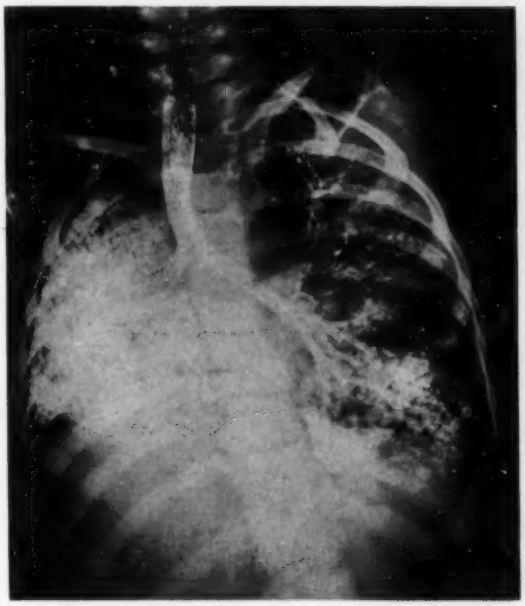

Fig. 4. (G. B.) Bronchograms show a single right main bronchus, with no evidence of a bronchus to either the middle or lower lobes on the right side.

atelectasis of the right middle and lower lobes. Only a single bronchus was found on the right side, and it communicated only with the upper lobe. Very little attention has hitherto been given such conditions, except in the case of foreign bodies. Two of the cases of tracheobronchial tree anomaly (P. G. and J. C.) showed findings consistent with pulmonary emphysema as a result of intrinsic bronchial obstruction due to a foreign body. The roentgenograms were classical—showing increased aeration of the affected lung, displacement of the heart and mediastinum to the opposite side, widening of the interspaces and depression of the diaphragm. In 1 of the patients (P. G.) (Fig. 5), who was studied in 1931, no bronchoscopy was performed, but postmortem examination disclosed merely an absence of the cartilaginous rings of the main bronchus. During inspiration the bronchus probably dilated and air entered the lungs; but on expiration the bronchial walls collapsed, producing a "ball-valve" action which entrapped the inspired air. The total effect on the lung was that of obstructive emphy-

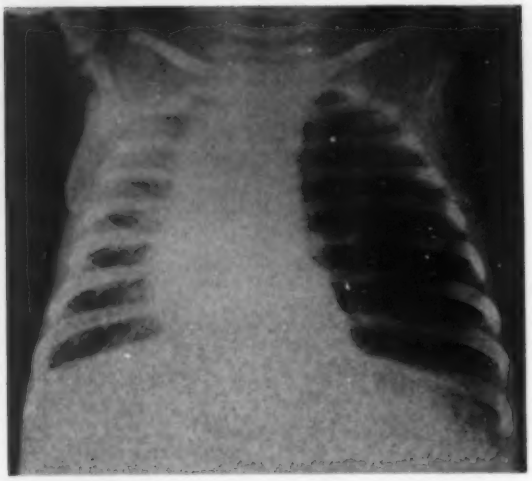

Fig. 5. (P. G.) Obstructive emphysema of the left lung, associated with absent cartilaginous rings of the left main bronchus.

sema, exactly similar to that caused by a bronchial foreign body. Another case (J. C.) (Fig. 6) showed exactly the same physical and roentgen findings, while bronchoscopic examination revealed complete collapse of the bronchial walls during expiration. The bronchoscope could easily be passed down the bronchus, and no constriction was noted. As it was withdrawn, the walls completely collapsed below it, coincidental with a "flapping" noise noted during each expiratory phase. Very recently, postmortem examination was performed on a child who died suddenly during a general anesthetic for an orthopedic operation. At autopsy, among other congenital anomalies, the orifices of some of the bronchi were noted to be in a collapsed state but were very easily opened by slight traction on the bronchial and tracheal walls. Microscopic studies showed a deficiency of the cartilaginous rings in the locality of the collapsible bronchi. Unfortunately, we did not have an opportunity to perform a bronchoscopic examination of this child during life.

In 1932, Bremer[2] reported the addition to the Harvard Embryological Collection of a 16.5 millimeter human embryo with a large bronchus arising from the right side of the trachea a short distance above the bifurcation and extending caudally. He states that of the 80 human embryos in the Collection ranging from 5 to 45 mm., 3 others showed a tracheal bronchus. Two of them had two tracheal buds. Five of the six tracheal buds were on the right side and only one on the left side. Apparently a tracheal bronchus is a normal phenomenon in certain species, such as the sheep and the pig. Bremer is impressed with the 5 per cent incidence of such findings in the human embryo collection and its relative rarity in adults. He therefore feels that many tracheal buds probably disappear during the process of development, possibly the result of simple absorption. This may account for certain irregularities of the tracheal cartilages seen in adult life, as well as weak areas in the musculature, tracheal diverticula or other anomalies. The anomalous tracheal buds may develop into accessory bronchi to normal apical lobes or into bronchi to accessory apical lobes or even into bronchi to a third lung in the mediastinum. The patient (R. R.) (Fig. 1 and 2) who had had pneu-

Fig. 6. (J. C.) Bronchograms show considerable narrowing of the entire tracheobronchial tree, with obstructive emphysema of the left lung, associated with absence of the cartilaginous rings of the left main bronchus.

monia recur in the right upper lobe on several occasions, showed an upper lobe bronchus arising from the right side of the trachea, in the same manner as the embryo demonstrated.

CASE REPORTS

Case I. E.M. (C.H.No. 192533) This patient, female, aged two years and nine months, was admitted to the Medical Service on October 26, 1937, with a history of cough since the age of two months. Her family history was significant only in that an aunt had died at the age of twenty of congenital heart disease. The baby was delivered three weeks prematurely and weighed only 4½ pounds. The only abnormalities noted at birth were an absent left hand and a left facial weakness. The facial palsy subsided spontaneously. Several weeks after birth, the patient developed an unproductive cough associated with noisy respirations, and a poor gain in weight. Examination at the time of admission showed a child whose left chest measured 8.5 cm. in circumference and the right 9 cm. There was no obvious flattening. On percussion, the chest was dull to flat throughout the left side and fremitus and breath sounds were absent. The heart was displaced to the left. The left hand was absent. The roentgenograms (Fig. 7) showed no abnormality of the bony thorax except that the left hemithorax was considerably smaller than the right. The heart and mediastinal structures showed a marked shift to the left. The right lung was

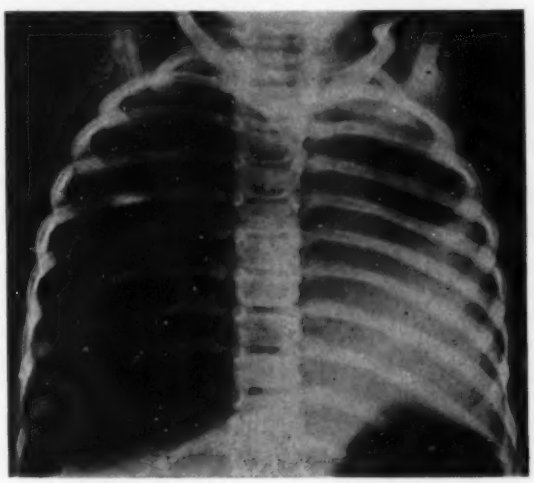

Fig. 7. Case I. Agenesis of the left lung.

Fig. 8. Case I. Agenesis of left lung, showing small bronchial rudiment.

emphysematous and extended far beyond the midline to the left. The remaining portion of the left hemithorax was opaque. On October 30, 1937, bronchoscopy was performed under avertin-ether anesthesia and lipiodol injected into the tracheobronchial tree. There appeared to be an abrupt ending of the left main bronchus about 1 cm. beyond the bifurcation. Bronchograms (Fig. 8) showed a moderate shift of the trachea to the left and no definite abnormality of the right bronchial tree. The left main bronchus was about 1 cm. in length, quite narrow and with a blunted and abrupt termination. This patient has continued to live an essentially normal life. In April, 1941, mastoidectomy was uneventfully performed under general anesthesia. In July, 1942, her tonsils and adenoids were removed under general anesthesia without event. At the present time, she is eight and one-half years of age and is still living a normal life without restriction of activity.

Case II. B. W. (C. H. No. 229558) This baby girl, aged four months, was admitted to the Infants' Hospital on February 22, 1939, because of respiratory embarrassment since birth. The family history was essentially negative. The patient's birth was uneventful. At two weeks of age, it was first noted that her respirations were noisy and rapid. When disturbed there was cyanosis. Examination at the time of admission to the hospital showed an infant with a harsh inspiratory crow and definite retraction of the

Fig. 9. Case II. Agenesis of right lung, showing small bronchial bud.

interspaces on the left side. The right side of the chest moved very little with respirations. The trachea was deviated to the right side. There was dullness and flatness over the entire right chest, while the left chest was hyperresonant. The breath sounds on the left were loud and on the right were diminished to absent. Congenital atelectasis or agenesis of the right lung was suspected, so bronchoscopy was performed on February 28, 1939, under avertin-ether anesthesia. The trachea was found to be displaced to the right and no right bronchus was visible. Lipiodol bronchograms (Fig. 9 and 10) showed a marked shift of the trachea to the right and no definite abnormality of the left bronchial tree. There was a small bud-like structure which filled with lipiodol and apparently represented an abortive right main bronchus. The patient did quite well for two days after bronchoscopy. At that time, she began to develop increasing dyspnea with some cyanosis and showed signs of pneumonia. On the sixth postoperative day, with a temperature rising to 106° F. and with increasing signs of infection, the patient died. Autopsy showed an absent right lung and bronchus, a patent ductus arteriosus, hypoplasia of the spleen, kidney and liver and an accessory spleen. (The lung is reproduced in Figure 11.) There was a rather marked interstitial pneumonia. At the usual point of origin of the right main bronchus there was a small bud-like structure which corresponded to the right lung. There was no pulmonary artery and no pulmonary vein.

Case III. J. F. (C. H. No. 235096) This six month old baby boy was admitted to the Surgical Service on November 8, 1939, because of a congenital deformity of his left external ear. The family history was entirely negative. The birth history was also normal. At birth, the malformed left auricle was noted as the only abnormality. At the time of admission, examination showed a deformity of the left auricle. The patient was noted on physical examination to have a somewhat diminished chest expansion on the left side, where there was definite dullness and flatness throughout, with markedly diminished to absent breath sounds. Respirations were slightly rapid, but not difficult. The heart and trachea were displaced to the left side. Roentgenograms (Fig. 12) showed no ab-

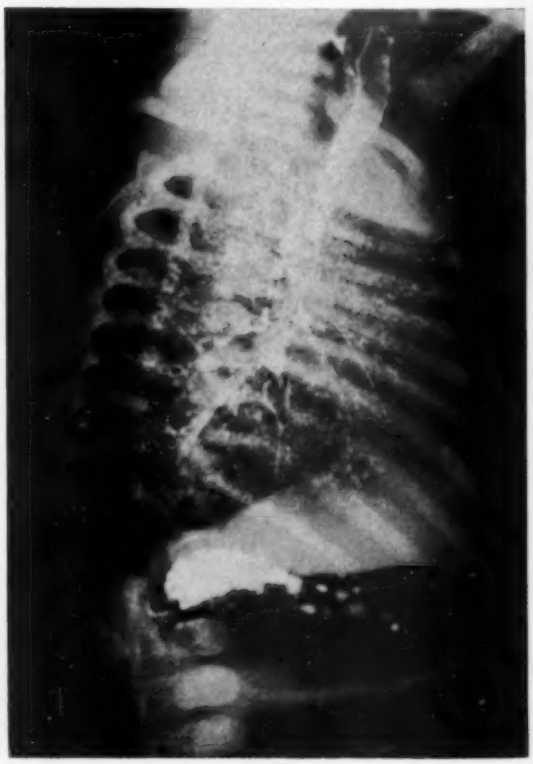

Fig. 10. Case II. Agenesis of right lung, oblique view.

normality of the thorax except that the left hemithorax was considerably smaller than the right, with a marked shift of the heart and mediastinum to the left, so that the heart was entirely within the left hemithorax. The right lung was emphysematous and extended to the left beyond the midline. The left hemithorax was opaque. It was felt advisable to perform

Fig. 11. Case II. Pathological specimen showing agenesis of right lung.

bronchoscopy and inject lipiodol. On the second hospital day, this procedure was carried out under ether anesthesia. Bronchograms (Fig. 13) showed that the right bronchial tree was apparently normal. The left main bronchus was about 3 cm. in length and formed only a minimal angle with the trachea at the bifurcation. The bronchus was narrowed and quite irregular and had two minute prolongations, apparently representing the first subdivision. Electrocardiogram showed no axis deviation, but unusually wide deflection in leads 1 and 3. Barium studies of the esophagus and stomach were nor-

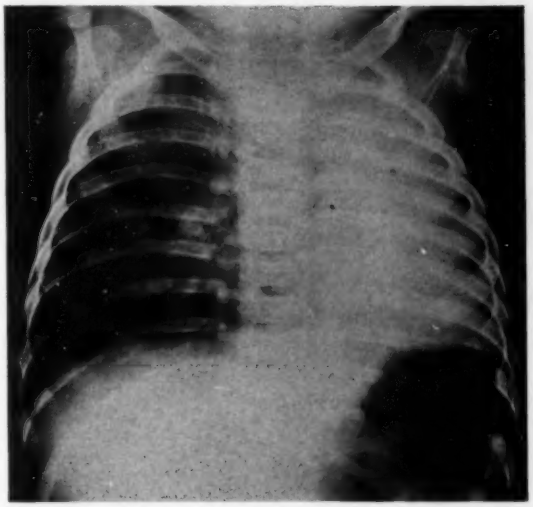

Fig. 12. Case III. Agenesis of left lung.

mal. The patient was discharged home in good condition ten days after admission. Since that time, he has lived a perfectly normal life. He was last heard from a few months ago and was planning to come back to the hospital for a plastic operation to his left external ear. He apparently has never had symptoms related to the absent lung.

Case IV. J. R. (C. H. No. 263317) This baby girl, aged four months, came into the Out-Patient Department of the hospital on June 25, 1942, with a story that her respirations had al-

Fig. 13. Case III. Agenesis of left lung, showing marked hypogenesis of left bronchial tree.

FIG. 14. Case IV. Agenesis of right lung.

ways been rapid, but never labored, and she had had no cyanosis. Two weeks before admission to the Out-Patient Department, a roentgenogram of her chest had been taken and a congenital anomaly suspected. The family history was negative. Birth history was also negative. Examination showed diminished expansion of the chest on the right side, with a scoliosis in the thoracic region with a convexity to the left. The

FIG. 15. Case IV. Agenesis of right lung, showing marked distortion of the tracheobronchial tree, with absence of the right main bronchus.

right side of the chest was flat to percussion and no cardiac dullness was found on the left side. The heart and trachea were displaced to the right side. The breath sounds on the right were extremely distant. Roentgenograms (Fig. 14) showed a fairly marked left dorsal scoliosis with multiple congenital anomalies of the high dorsal vertebrae, including several hemivertebrae and a spina bifida. The ribs on the right

FIG. 16. Case IV. Agenesis of right lung, oblique view.

also showed multiple congenital abnormalities, with fusion of the third to sixth ribs on the right. There was a marked shift of the heart and mediastinum to the right and the right hemithorax was opaque. The left lung showed considerable emphysema. The patient was admitted to the hospital and on July 3, 1943, bronchoscopy was performed under ether anesthesia. The bronchoscope was passed to the region where the bifurcation ordinarily should have been, but met complete obstruction. It was impossible to pass the bronchoscope beyond this region, either to one side or to the other. Lipiodol was injected and the bronchograms (Fig. 15 and 16) showed that the entire trachea was somewhat narrowed and showed a

rather marked shift to the right and marked convexity to the right and posteriorly. The trachea continued directly into the left main bronchus, but showed no definite abnormality of the main portions or of its subdivisions. There was no evidence of a right main bronchus. The patient was discharged home five days after bronchoscopy in good condition and has lived an uneventful life since that time. She was last seen a few months ago, at which time she had no complaints and was in excellent physical condition.

Case v. D. S. (C. H. No. 232923) This three weeks old baby boy was first admitted to the hospital on June 2, 1939, at which time a hare-

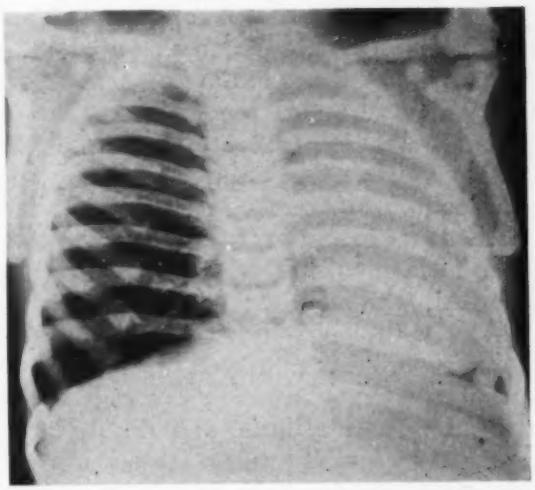

Fig. 17. Case v. Agenesis of left lung.

lip was repaired under ether anesthesia. His family history and birth history were negative. After the harelip operation, he had recurring cyanosis for the first two postoperative days. Thirteen days later he was discharged home in good condition. No abnormality of his lungs was mentioned at this admission. He remained perfectly well until he was re-admitted, on July 6, 1942, at the age of three years and two months, for repair of the cleft palate. On the routine admission examination at that time, his chest presented definite abnormalities. The thoracic cage was symmetrical, but the respiratory excursion on the left side seemed to be somewhat diminished. There was marked flatness of the left side of the chest, with marked displacement of the heart to the left. The breath sounds were very distant on the left,

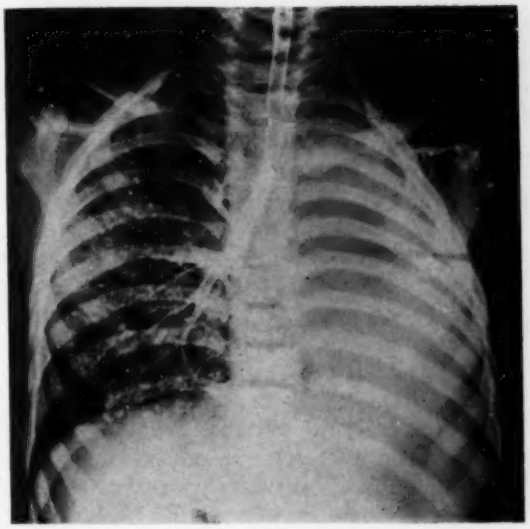

Fig. 18. Case v. Agenesis of left lung, showing absence of left main bronchus.

but heard at the apex and along the left border of the sternum. Roentgenograms (Fig. 17) showed no definite abnormality of the thorax except that the left hemithorax was considerably smaller than the right. There was a marked shift of the heart and mediastinum to the left

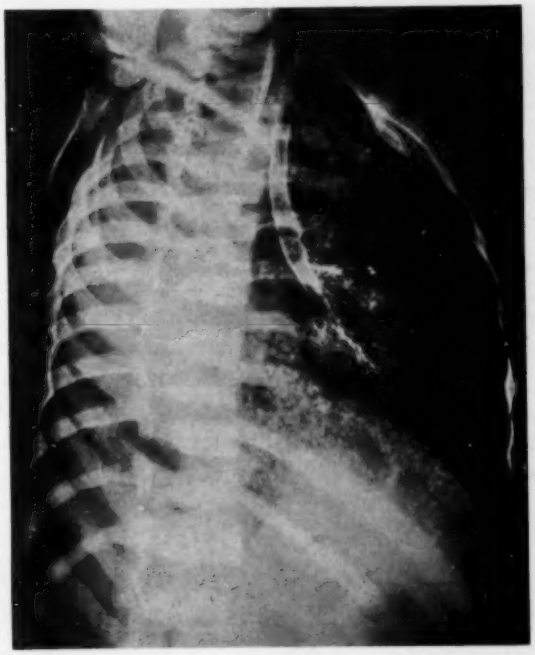

Fig. 19. Case v. Agenesis of left lung. Oblique view.

and the left hemithorax was opaque. The right lung showed considerable emphysema and extended beyond the midline to the left. It was felt that bronchoscopy should be carried out. This was accordingly done on July 8, 1942. No bifurcation was seen, but the bronchoscope could be passed for a relatively long distance through what appeared to be an abnormally long trachea. The trachea, however, was somewhat narrowed. Lipiodol bronchograms (Fig. 18 and 19) showed no definite abnormality of the right bronchial tree and no evidence of a left bronchus. Two days after this procedure, his tonsils and adenoids were uneventfully removed under ether anesthesia. In September, 1942, he returned for a repair of his cleft palate, which was also done under general anesthesia. He was last seen during a check-up in the Out-Patient Department this year (1943) in excellent condition and apparently living a normal life.

These 5 cases of agenesis of the lung illustrate the fact that this deformity is not incompatible with a normal existence. Four out of these 5 patients are living perfectly normal lives and are not as yet handicapped by their defect. It is also interesting that all 5 cases showed additional congenital anomalies. In the first case, there was an absent hand. In the second case, there was a patent ductus arteriosus, accessory spleen with hypoplasia, and hypoplasia of the kidney and liver. In the third case, there was a congenital malformation of the external ear. In the fourth case, there were congenital anomalies of the vertebrae and ribs noted by the roentgenograms. In the fifth case, there was a harelip and a complete cleft palate. The cases in the literature also have showed very frequent associations of other congenital anomalies. For this reason, we feel that an inherent defect in the germplasm is probably responsible for this as well as the other associated congenital anomalies.

SUMMARY

1. Agenesis of the lung is a relatively uncommon congenital anomaly, and thus far only about fifty cases have been recorded. Of these, only about six have been diagnosed before postmortem examination.

2. From The Children's Hospital in Boston five cases of agenesis of the lung are reported, all of which have been diagnosed during life. Of these five patients, four are still living and well.

3. According to the literature, this anomaly occurs more commonly in males than females, and is noted more often on the left side than the right. In our cases three of the patients were females, and the absent lung was found on the left side in three cases.

4. The condition is probably the result of an inherent defect in the germ plasm, as there are often associated congenital anomalies. All of our five patients showed additional abnormalities of development.

5. The symptoms are so inconstant or lacking that roentgen studies plus bronchoscopy with lipiodol injection of the tracheobronchial tree are the recommended methods for diagnosis.

6. The prognosis should always be guarded, although the condition is compatible with longevity. Three of the patients reported in the literature lived well over fifty years. Of our five cases four are still living normal lives, and the oldest is over eight years of age.

7. In cases of persistent emphysema or atelectasis, or cases of supposed unresolved pneumonia, or recurrent pneumonia in the same lobe, congenital anomalies of the tracheobronchial tree must be considered.

8. Case histories of five patients with agenesis of the lung are presented, accompanied by their respective roentgenograms and bronchograms.

9. Bronchograms of five cases of tracheobronchial tree anomalies are also presented.

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PULMONARY DISEASE ASSOCIATED WITH MEGA-ESOPHAGUS

By H. STEPHEN WEENS, M.D.

From the Department of Roentgenology, Grady Hospital and Emory University School of Medicine
ATLANTA, GEORGIA

INTRODUCTION

ALTHOUGH the condition commonly described as mega-esophagus or cardiospasm has been carefully studied in numerous papers, little attention has been given to the occurrence of pulmonary lesions which may accompany this disorder.

Recently a small group of patients with mega-esophagus was observed at Grady Hospital which presented interesting pulmonary manifestations, such as lung abscess, chronic and acute aspiration pneumonitis, and bronchiectasis. It will be the purpose of this paper to emphasize the occurrence of these pulmonary lesions, the symptoms and signs of which may completely overshadow the features of the associated esophageal disease. The recognition of the association of these conditions is of clinical importance since the presence of mega-esophagus has frequently remained unrecognized for many years.

A review of the literature reveals that this subject has received surprisingly little attention. Vinson[14] reported the occurrence of a pulmonary abscess in a patient with mega-esophagus, which responded to conservative treatment. Sampson[8] discussed a similar case in which the presence of mega-esophagus was not discovered for many years. Aspiration pneumonitis as a complication of mega-esophagus was described by Cummins and Williams.[3] A similar observation was made by Baldwin[1] and recently by Warring and Rilance.[15] The simultaneous occurrence of bronchiectasis and mega-esophagus has been recorded by Schrire[9] and Reeke.[7]

The reports in which larger series of patients with mega-esophagus were investigated draw little attention to the occurrence of pulmonary manifestations. Sturtevant,[10] in a summarizing report and review of the literature, referred to a case of Thomas and Jewett,[11] in which a patient with mega-esophagus developed lipoid pneumonia as the result of aspiration of milk and cream. Verbrycke,[12] in a study of 100 cases of "cardiospasm," does not mention chest complications. Vinson,[13] in a large series of 415 cases, stated that in 49 patients respiratory symptoms were present, usually "consisting of nocturnal cough, and dyspnea after meals, due to regurgitation or pressure from the dilated esophagus filled with food." There were no roentgenological findings or clinical signs of pulmonary disease described in this study.

During the last four years 15 cases of mega-esophagus have been observed in the Department of Roentgenology of Grady Hospital. In 5 of these cases pulmonary disease was demonstrated roentgenologically. Two other patients revealed repeated pleural effusions. Since one of these patients developed tuberculosis these two cases are not included in this study. This would indicate a rather high incidence. However, it is felt that no definite statistical conclusions should be drawn from such a small series.

In the following case reports various forms of pulmonary disease, associated with mega-esophagus, are illustrated.

REPORT OF CASES

CASE 1. *Mega-esophagus and Pulmonary Abscess.*

J. S., a colored male, aged twenty-nine, was apparently well until the middle of September, 1942, when he became ill with cough, fever, and a chill. On a visit to the emergency clinic a chest roentgenogram was taken, which showed an abscess cavity with a horizontal fluid level in the right upper lobe (Fig. 1). The patient returned home and was treated by his private physician with sulfathiazole. He began to bring

up foul-smelling sputum which was occasionally blood stained and he remained in bed for one month. After this interval he showed some improvement. As soon as he returned to work the sputum became copious again and he complained of chest pain. Increasing weight loss, weakness, and daily fever made him seek admission to the hospital.

The physical examination revealed signs of consolidation over the right upper and posterior lung field. The laboratory findings showed a normal red blood cell count and moderate leukocytosis. The Kahn reaction was negative. Repeated sputum examinations revealed a few gram-positive diplococci; there were no acid-fast bacilli detected.

Roentgenological Findings. The first examination (October 9, 1942) showed an abscess cavity, measuring about 2 cm. in diameter, in the apical portion of the right upper lobe (Fig. 1). The cavity showed a horizontal fluid level and was surrounded by considerable parenchymal reaction. The mediastinal shadow on the right side protruded into the right lung field and formed an angle which pointed to the midline in the region of the right lung root. On account of the peculiar mediastinal shadow the esophagus was investigated upon his return to the hospital (January 7, 1943). It was found to be markedly dilated, displacing the trachea anteriorly (Fig. 2). The right lung root caused a characteristic pressure defect on the wall of the dilated esophagus. The fluid level was no longer visible in the abscess cavity, but the density in the right upper lobe was larger in size and had a somewhat honey-combed appearance. Subsequent examinations showed satisfactory decrease in the size of the parenchymal lesions.

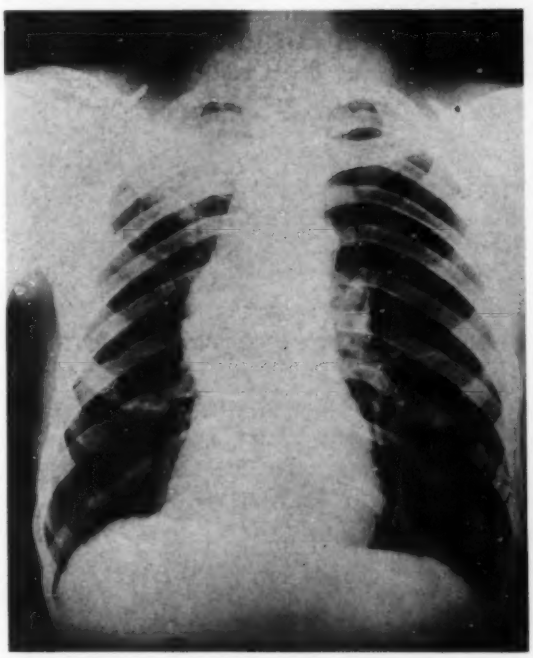

Fig. 1. Case 1. Pulmonary abscess in the right infraclavicular lung field. Angular mediastinal shadow due to dilated esophagus.

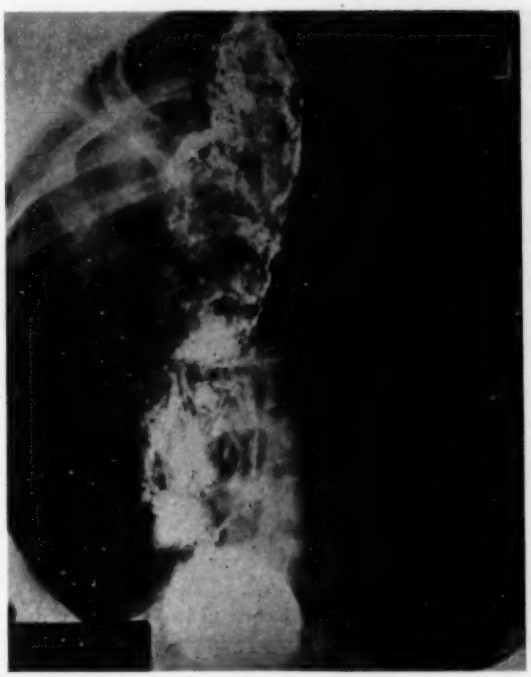

Fig. 2. Case 1. Dilated esophagus after administration of barium.

An esophagoscopic examination revealed a markedly dilated esophagus, the lower segment of which was resting on the diaphragm. The cardia was found wide open.

After the diagnosis of mega-esophagus was established the symptoms of the patient were re-investigated. After repeated questioning he admitted that he had been having difficulty in swallowing for over ten years and that his esophagus had been previously dilated. He also stated that occasionally, after going to bed, he would regurgitate material which would choke him.

The patient left the hospital against medical advice.

Comment. A patient with mega-esopha-

Fig. 3. Case II. Mega-esophagus outlined with barium. Note widening of mediastinal shadow and bilateral aspiration pneumonitis.

gus developed a pulmonary abscess, the symptoms and signs of which dominated the clinical picture. The esophagus showed very marked dilatation and produced a somewhat peculiar angulated mediastinal shadow. The abscess was believed to be the result of aspiration of esophageal contents into the right upper lobe bronchus.

Case II. *Mega-esophagus and Aspiration Pneumonitis.*

W. C. G., a colored female, aged thirty-seven, was admitted to Grady Hospital for surgical removal of a pelvic tumor. The history did not reveal any respiratory or digestive complaints. On physical examination the thyroid gland was bilaterally palpable and enlarged. The lungs were clear on auscultation. A large mass filled the lower abdomen and pelvis, extending upward to the umbilicus. The red blood cell count was 3,730,000 per cubic millimeter, the hemoglobin content 12 gm. per 100 cc., and the white blood cell count 7,750 per cubic millimeter. Under spinal anesthesia the uterus, both tubes, and the ovaries were removed. The pathological examination of the surgical specimen revealed leiomyomata of the uterus, simple cysts of both ovaries, and a Brenner tumor of the right ovary.

After operation the patient developed intermittent fever. On the sixth postoperative day cough and coryza were noted. The cough was productive and the sputum consisted of fairly large amounts of yellowish material. The right chest was filled with coarse bubbling râles, a few fine râles were heard on the left side. The sputum showed numerous long-chained streptococci and no evidence of acid-fast organisms. The patient was treated with sulfathiazole and developed fever, thought to be caused by the drug. After chemotherapy was discontinued the patient improved and became symptomless.

Roentgenological examination of the chest (May 20, 1942) revealed a fine interstitial fibrosis throughout the midportions of both lung fields, extending from the hilar areas toward the periphery, more extensive on the right side. Several coarse mottled densities were superimposed on this fine granular appearing lung pattern. There was a large soft tissue mass overlying the right heart border, extending from the right diaphragm toward the base of the neck. The upper segment of this shadow consisted of an air column overlying the trachea. In view of these findings mega-esophagus was suspected and confirmed by barium meal (Fig. 3). Subsequent examinations revealed that the mottled densities in both lung fields had partially resolved. The fine fibrosis did not show any changes.

After the esophageal disease was diagnosed the patient still would not admit any digestive complaints. On repeated questioning she finally stated that she occasionally had gas pains which were relieved by milk of magnesia.

Comment. This patient demonstrates the presence of acute and chronic pulmonary disease with mega-esophagus. Roentgenologically and clinically the patient developed an acute inflammatory process of the lungs during her postoperative course. It was shown roentgenologically that, in addition to acute pulmonary changes, there was rather extensive interstitial fibrosis in both lung fields. It is believed that bed rest and sedation may have favored aspiration of esophageal contents and produced the acute inflammatory changes.

From the clinical standpoint the almost complete lack of digestive symptoms is interesting.

Case III. *Mega-esophagus and Pulmonary Fibrosis.*

H. C., a colored female, aged twenty-six, visited the out-patient department of Grady Hospital complaining of dysphagia, discomfort over the lower sternum, and shortness of breath. For three years she had noticed increasing difficulty in swallowing. She frequently regurgitated undigested food and would often be awakened at night choked by mucus and food flowing from her nose and mouth. During the last three years the patient had lost 25 pounds in weight. She had suffered from a cough of one year's duration which had become severe during the winter before hospital admission. She stated that her coughing was considerably worse during the night. There had been shortness of breath on exercise and a sensation of pressure in her chest.

Physical examination after admission to the hospital (October 18, 1943) revealed a slight diminution of breath sounds to the right of the spinal column. The lungs were otherwise clear and resonant. The examination of the heart revealed nothing abnormal. On deep palpation slight tenderness of the epigastrium was noted. The pelvic examination disclosed bilateral tubovarian masses. The fingers and toes showed clubbing with convexity of the nails. The red blood cell count was 4,450,000 per cubic millimeter, the hemoglobin content 7.7 gm. per 100 cc., the white blood cell count 7,800 per cubic millimeter. There were no abnormal urinary findings. The Kahn and Frei tests were negative. The electrocardiogram showed normal tracings. The vital capacity was 2.1 l. Cultures from the bronchial tree, obtained on bronchoscopy, revealed alpha-hemolytic streptococci and no acid-fast organisms.

Roentgenological examination revealed that the esophagus was considerably dilated. The lower portion of the esophagus was somewhat redundant and terminated in a funnel-shaped segment. The wall of the lower esophagus showed vigorous peristalsis and, occasionally, a small amount of barium passed into the stomach. The barium was retained in the esophagus for more than three hours. The lungs showed a fine interstitial fibrosis which was most marked in the base of the right upper lobe and in both lower lobes, producing a granular lung pattern (Fig. 4). No mediastinal shift was demonstrated. The excursion of the diaphragms was slightly diminished on both sides.

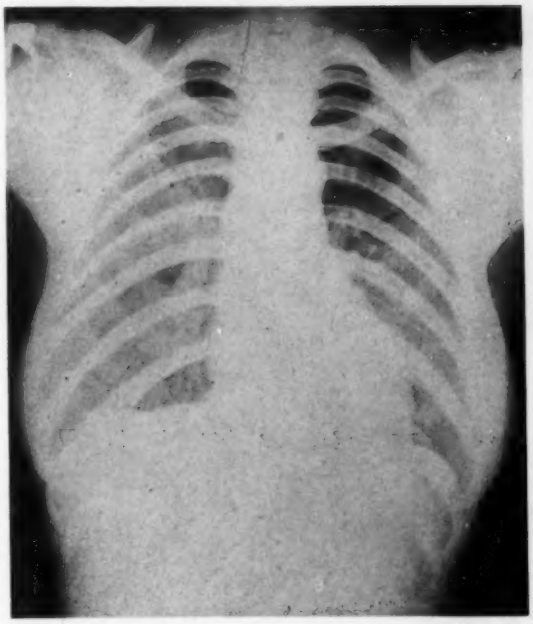

Fig. 4. Case III. Diffuse pulmonary fibrosis in right upper and both lower lobes. Slight widening of mediastinal shadow due to mega-esophagus.

Re-examination of the chest after two months revealed no definite change in the pulmonary findings. The roentgenological findings were confirmed by esophagoscopy.

Comment. In this case the association of mega-esophagus and diffuse interstitial pulmonary fibrosis is noted. Symptoms of dysphagia had been present for three years. For about one year the patient had had shortness of breath on exercise. Clubbing of the fingers and toes accompanied the chronic pulmonary changes which are believed to be the result of aspiration pneumonitis.

Case IV. *Mega-esophagus and Aspiration Pneumonitis.*

A. L., a white female, aged eighteen, was admitted to Grady Hospital in December, 1938, complaining of difficulty in swallowing, of two years' duration. She had a choking sensation in her chest and would frequently vomit immediately after meals. Preceding this, the patient had suffered from colds, coughs, and gradual loss of weight. The physical examination and the laboratory findings were not significant.

Roentgenological examination (December 9,

FIG. 5. Case IV. Aspiration pneumonitis, both lung bases. Air column in upper esophagus clearly visualized.

1938) revealed marked dilatation of the esophagus, characteristic of mega-esophagus. The roentgenological diagnosis was confirmed by esophagoscopic examination. After discharge from the hospital the patient was treated by esophageal dilatation in the out-patient department until June, 1941.

During the following winter she suffered from a very annoying, constant cough. In September, 1942, she became ill with fever, cough, chest pain, and chills. The patient consulted her family physician on November 7, 1942. A roentgenological examination on this day revealed coarse, mottled, confluent densities in both lung bases, obscuring both cardiophrenic angles (Fig. 5). She was admitted to another hospital where she remained for two weeks.

The patient was re-examined at Grady Hospital January 19, 1943. On roentgenological examination the dilatation of the esophagus had not changed in extent. No definite pulmonary pathologic condition was demonstrated. The patient stated, however, that she had been suffering from chronic cough during the winter months. There were no definite digestive complaints.

Comment. In a young adult the association of mega-esophagus and acute pneumonia is demonstrated. The presence of a very persistent chronic cough and frequent occurrence of colds are outstanding features in the history of this patient. During a febrile episode the presence of pneumonia in both lung bases was demonstrated roentgenologically. It is highly suggestive that the acute inflammatory process of the lungs was the result of aspiration.

CASE V. *Mega-esophagus and Bronchiectasis.*

E. F., a white female, aged twenty-eight, was first seen in the prenatal clinic of Grady Hospital in April, 1940, when she was six months pregnant. Her history revealed that she had the usual childhood diseases, including whooping cough and several attacks of "double pneumonia." For the past fifteen years the patient had been suffering from a chronic productive cough which was occasionally associated with febrile episodes. Her sputum was frequently blood stained and amounted to about half a cupful daily. During the last year she had frequent headaches in the region of the left frontal sinus. Since the first week of her pregnancy she complained of choking sensations in her throat and chest and inability to keep food on her stomach. The vomiting was often accompanied by severe coughing spells. The patient had had three normal pregnancies and one miscarriage, none of which was associated with similar digestive disturbances.

On July 2, 1940, the patient delivered a normal infant at Grady Hospital. A physical examination at that time revealed numerous coarse râles over both lung bases. After discharge from the hospital the patient was seen at intervals in the out-patient department, where she was treated for chronic sinusitis. She still complained of coughing, headaches, and thick yellowish nasal discharge. In June, 1942, her digestive complaints became much worse. She stated that she vomited everything she ate. The patient was re-admitted to the hospital and her condition improved considerably under medical treatment. The physical findings were unchanged. The red blood cell count was 4,200,000 per cubic millimeter, the hemoglobin content 11 gm. per 100 cc., and the white blood cell count 16,900 per cubic millimeter with a normal differential. The sputum showed numerous chains of gram-positive cocci, but no tubercle bacilli. A third and fourth hospital admission for study followed.

Roentgenological Findings. The first examination (August 8, 1940) revealed accentuation of the lung markings and fibrosis in both lung bases. An air column in the upper mediastinum, characteristic of mega-esophagus, is distinctly visible on this chest roentgenogram. A gastrointestinal examination on July 1, 1942, revealed marked dilatation of the esophagus. There was retention of the barium in the stomach though no organic obstruction was demonstrated. A bronchogram (April 2, 1943) demonstrated cylindrical dilatation of the bronchial tree of both lower lobes, the bronchi of the left lower lobe showing a tendency toward clubbing (Fig. 6). A distinct fluid level was seen in the mid-portion of the dilated esophagus.

Comment. This case illustrates the association of mega-esophagus with bronchiectasis. The respiratory symptoms were evident many years before the digestive symptoms were noted. This may be due to the fact that bronchiectasis preceded the development of mega-esophagus. However, since mega-esophagus may not produce significant clinical symptoms, it may well have developed at the same time or even have preceded the bronchiectasis.

Fig. 6. Case v. Bronchogram demonstrating bilateral bronchiectasis. Note horizontal fluid level in dilated esophagus.

DISCUSSION

Clinical Manifestations. A discussion of the symptoms and signs of mega-esophagus seems to be unnecessary, since the clinical features of this condition are sufficiently well known and have been described in excellent studies.[4,6,10,12] It should, however, be emphasized that the digestive disturbances —especially in the presence of respiratory symptoms—may appear so slight to the patient that he will frequently conceal their presence. They may be very vague and misleading. In 2 of our patients, symptoms of esophageal disease were detected only after the history of the patient was re-investigated. Another patient, even after the diagnosis was established, would not admit symptoms which would make the examiner suspect esophageal disease. It is of great importance to the clinician and to the roentgenologist to realize that mega-esophagus may exist even when clinical symptoms are minor or absent.

Roentgenological Features. Since the patient may present himself to the clinician or the roentgenologist with predominant respiratory symptoms, a gastrointestinal examination is frequently omitted. For this reason, it may be well to emphasize those roentgenological features which aid in the diagnosis of mega-esophagus by roentgenographic and roentgenoscopic examination, without the use of contrast medium. The enlarged esophagus produces a widening of the mediastinal shadow toward the right side, extending from the base of the neck to the diaphgram. Depending on the degree of dilatation, this shadow will partially or completely obscure the right heart border and cardiac pedicle. If the dilatation is of slight or moderate degree, the shadow of the esophagus may simulate the right heart border. The outline of the esophagus is not necessarily smooth. Tendency toward pouch formation may result in a scalloped or lobulated, sometimes bizarre appearance of the mediastinal shadow as is illustrated in Fig-

ure 7. Frequently the esophageal contents cast a peculiar mottled shadow in the mediastinum due to numerous small gas bubbles dispersed in the retained material. The visualization of a horizontal fluid level in the esophagus, as a result of retained viscid material, is an extremely helpful sign (Fig. 6). In the lateral view, a characteristic displacement of the trachea toward the sternum is observed. Another sign of greatest diagnostic importance is the recognition of a double air column overlying the upper dorsal spine in the posteroanterior view. The central air column represents the trachea which is seen through the air column of the upper dilated esophagus (Fig. 8). Whenever one of these features is present on roentgenographic or roentgenoscopic examination, study of the esophagus by means of a contrast medium is indicated. This will readily enable the examiner to differentiate between esophageal dilatation and conditions simulating it, such as mediastinal disease and lesions of the spinal column.

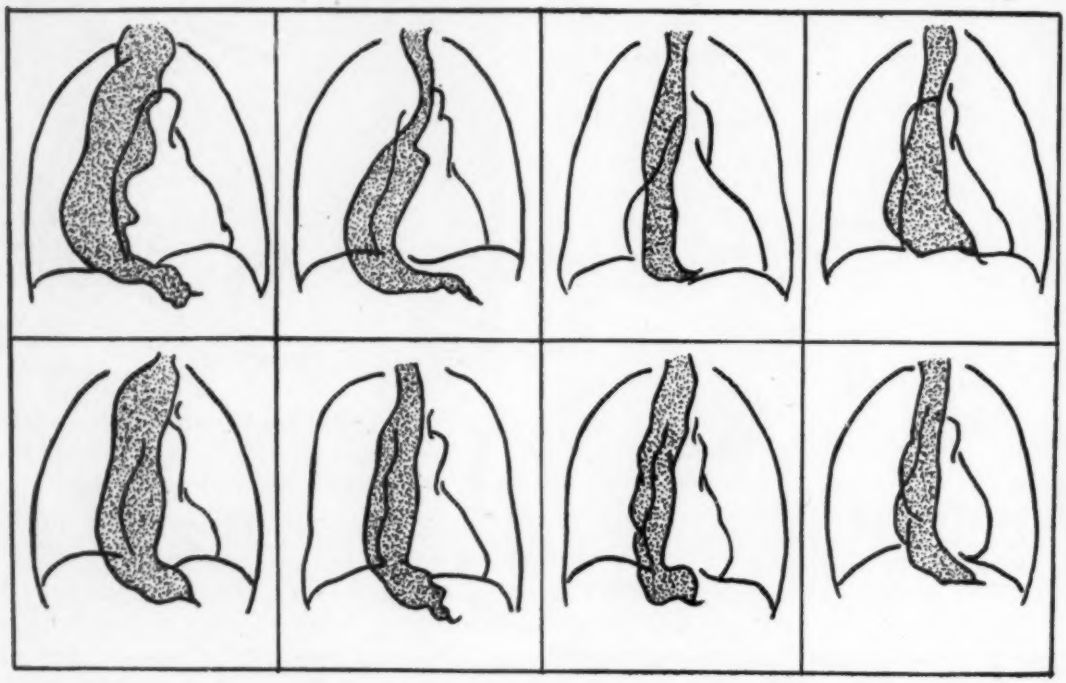

FIG. 7. Diagrammatic representation of 8 cases of mega-esophagus, showing the relationship between the right heart border and the dilated esophagus. Note variation in appearance of mediastinal shadow.

Pathogenesis of Pulmonary Disease. What explanation can be offered for the association of esophageal and pulmonary disease? Fistula formation between esophagus and trachea—as occasionally observed in esophageal carcinoma—was not demonstrated in any of our patients. Plummer and Vinson[6] stated that "nocturnal regurgitation, awakening the patient from sleep by food or mucous running out of the mouth or into the nose, producing cough, or staining the pillow by food particles or mucus," occurred in almost one-third of their patients. It is readily conceivable that material regurgitated into the pharynx may be aspirated into the bronchial tree. It must be remembered that food may be retained in the esophagus for many hours, with ample opportunity for rapid multiplication of bacteria.

Pulmonary fibrosis, as observed in Cases II and III, is believed to be the result of aspiration pneumonitis, whereby mechanical and chemical factors may play an important rôle. Cummins and Williams,[3]

Baldwin,[1] and Warring and Rilance[15] made a most interesting observation by demonstrating non-pathogenic acid-fast organisms in the sputum of their patients. These organisms resemble, morphologically, tubercle bacilli from which they are differentiated by rapid growth on ordinary culture medium and development of coccoid forms. Baldwin isolated acid-fast bacilli from various fruits and vegetables and discussed the possibility of aspiration of these organisms from the esophagus into the bronchial tree.

Warring and Rilance do not believe that these organisms influence the character of the pulmonary disease. We believe that bacteriologic studies of these patients should be conducted with sputum studies obtained by bronchoscopy to avoid contamination with esophageal contents. Bronchoscopic sputum studies of Case III did not reveal any acid-fast organisms. It has to be admitted, however, that this patient was not examined during a febrile episode. It is entirely possible that bronchoscopic sputum studies of these patients may yield interesting results as to the bacteriology and mycology of this chronic pulmonary disease.

The association of bronchiectasis and mega-esophagus deserves special consideration. Reeke[7] explained the simultaneous occurrence of mega-esophagus and bronchiectasis in a nineteen year old patient as a congenital disorder. This conception is not generally accepted. The rôle which pulmonary and bronchial disease play in the pathogenesis of bronchiectasis has been stressed in excellent studies.[2,5] If we accept the occurrence of pulmonary fibrosis, atelectasis, and pulmonary and bronchial infection as a result of aspiration of esophageal contents, all factors thought to be necessary for the development of bronchiectasis are present.

In Case V, the digestive symptoms were evident for a much shorter period of time than the respiratory ones. This does not necessarily indicate that the development of bronchiectasis preceded that of mega-esophagus. As stated above, mega-esophagus may not produce characteristic symptoms but may remain more or less silent. An interesting speculation as to the cause of the association of mega-esophagus and bronchiectasis was offered by Schrire,[9] who suggested that a faulty neuromuscular mechanism may be an etiologic factor in the development of both conditions.

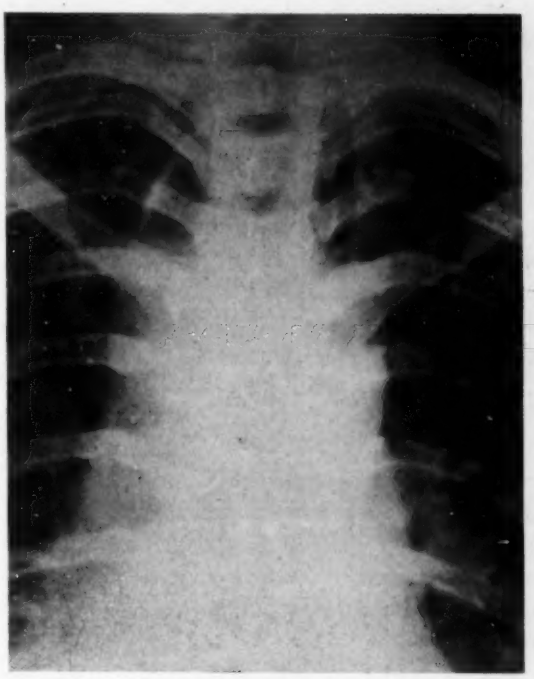

Fig. 8. Case IV. Double air column in upper mediastinum. Air column in trachea overlying spinous processes is seen through air column in upper esophagus.

CONCLUSIONS

During the past four years fifteen cases of mega-esophagus were observed. Five of the patients showed evidence of pulmonary disease. As stated in the introduction, we are not justified in drawing definite conclusions as to the incidence of these complications from such a small series of cases. However, the occurrence seems to be greater than is generally appreciated. The recognition of this association of diseases is important from the clinical standpoint as far as prognosis and treatment of the patient is concerned. Early institution of all measures which enhance esophageal emptying will prevent aspiration of re-

tained esophageal contents into the lungs.

There are two groups of patients in which this combination of diseases may easily be overlooked, and to which we should devote our special interest. The first group comprises those patients who are known to have mega-esophagus. This diagnosis may dominate the clinical picture to such an extent that the examiner may pay little attention to the respiratory complaints of the patient. Yet these respiratory symptoms may be the result of pulmonary changes easily recognizable on roentgenological examination. Therefore, in all patients with mega-esophagus, the presence of pulmonary disease should be suspected and searched for. The second group consists of patients who present evidence of pulmonary disease the etiology of which is not fully explained. It is entirely possible that some of these are associated with unrecognized mega-esophagus.

It is suggested that both the chest and the esophagus be examined roentgenologically, whenever either is suspected of harboring a chronic disease process.*

SUMMARY

1. The association of mega-esophagus with pulmonary lesions, such as lung abscess, aspiration pneumonitis, pulmonary fibrosis, and bronchiectasis is demonstrated.

2. It is believed that the pulmonary lesions are the result of aspiration of esophageal contents.

3. The incidence of pulmonary lesions in patients with mega-esophagus is thought to be higher than is generally appreciated. Pulmonary disease was demonstrated in five out of fifteen cases of mega-esophagus.

4. The roentgenological signs which aid in the diagnosis of mega-esophagus, without the use of contrast medium, are stressed.

5. The clinical importance of the association of pulmonary disease and mega-esophagus is discussed. Mega-esophagus may exist when digestive symptoms are minor or absent. It is suggested that pulmonary disease should be suspected in patients with mega-esophagus. In patients with pulmonary disease of unknown etiology, the presence of mega-esophagus should be ruled out.

* I am indebted to Dr. Avary M. Dimmock for follow-up studies on Case IV.

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Vol. 52, No. 5

PULMONARY SUPPURATION SECONDARY TO CARDIOSPASM

By I. BIRD-ACOSTA, M.D.

Department of Roentgenology, Hermann M. Biggs Memorial Hospital

ITHACA, NEW YORK

THERE are many reports in the literature concerning pulmonary suppuration as a result of esophageal overflow and aspiration of the esophageal contents. The causes of esophageal retention are numerous, and among them may be mentioned cancer of the esophagus, stricture following the ingestion of caustics, pulsion diverticulum, constriction of the esophageal lumen by pressure from adjacent tumors, foreign body in the esophagus, and cardiospasm. Of these, cardiospasm, though a fairly common clinical entity, is rarely considered when an explanation is sought for a chronic pneumonitis of unkown origin. Vinson,[11] Sampson,[7] Baldwin,[1] and more recently Warring and Rilance,[12] have reported isolated cases in which the relationship between the two conditions is clearly shown.

Three cases of this nature have come under our observation during the past four years.

REPORT OF CASES

CASE 1. A. S., a white woman, aged fifty-three, was admitted to the hospital on January 21, 1939, complaining of cough and expectoration, present since November 24, 1938. The patient stated that she was taken ill on that day with what was described as grippe, the onset being chills and generalized muscular aches and pains. Cough and mucopurulent expectoration in a moderate degree developed promptly but subsided in about two weeks. Weakness and ease of fatigue persisted, however, and on checking her temperature the patient found that she had fever in the afternoon ranging up to 99.8°F. On January 10 she was taken acutely ill with prostration and high temperature, and on the following day had a fairly sudden onset of severe cough with rapid production of large amounts of bloody purulent sputum which in the first twenty-four hours amounted to approximately 8 oz. The sputum tasted very foul, but she was unable to state whether or not it had a foul odor. At this time an aching pain first appeared in the right anterior chest, but later it became localized at the costal margin. Cough and expectoration had remained unchanged and night sweats had been noted since January 11. The patient had had some difficulty in swallowing food since 1936 when she began to choke at the table. This became progressively worse so that at the time of her admission it was difficult for her to swallow anything but liquids. The past and family histories were noncontributory.

Physical examination revealed a somewhat apathetic, elderly woman, coughing productively at intervals, and apparently acutely ill. The positive physical findings related to the right lung, where the percussion note was impaired above the level of the eighth dorsal spine, and tactile and vocal fremitus slightly increased posteriorly. The breath sounds were bronchovesicular throughout, and a moderate number of fine and medium tussic and posttussic râles were heard in the intrascapular area above the level of the ninth dorsal spine.

Laboratory findings on admission were characterized by a leukocyte count of 27,800 cells of which 84 per cent were neutrophiles. The red blood count was 4,300,000 and the hemoglobin content 13 grams per 100 cc. The urine examination and Wassermann reaction were negative. Repeated studies of the sputum were all negative for acid-fast bacilli. No spirochetes were found in the sputum and no predominant organisms were isolated.

A roentgenogram of the chest (Fig. 1) showed a dense area of infiltration in the right lung measuring 5 by 6 cm. Its central portion appeared excavated and contained a fluid level. With the aid of a lateral roentgenogram the area of disease was placed at the upper pole of the lower lobe.

A diagnosis of lung abscess was made and the patient placed on a regimen of postural drainage.

On February 1, roentgenological studies of the esophagus were carried out which showed a marked narrowing of the distal end of the

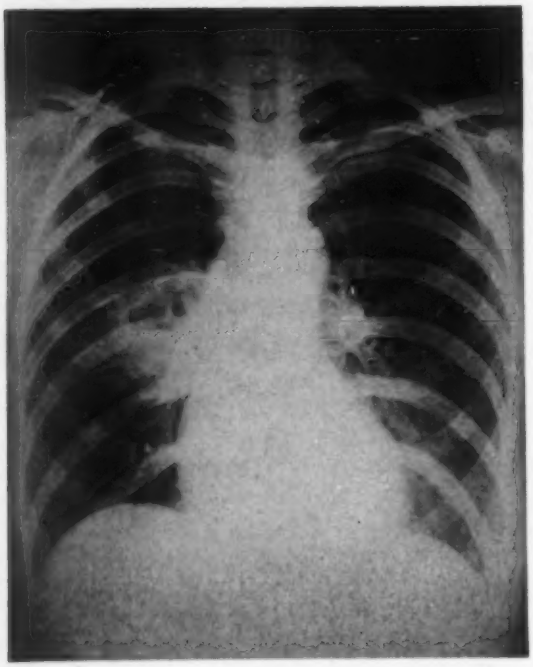

Fig. 1. Case 1. Roentgenogram of the chest on admission. Note the area of infiltration in the neighborhood of the right hilum and the central rarefaction and fluid level.

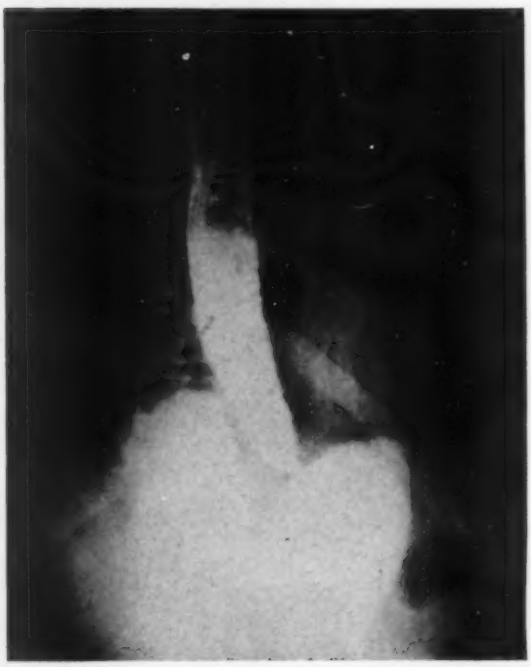

Fig. 2. Case 1. Oblique view of the barium-filled esophagus showing the spasm at the cardia.

esophagus and a pronounced degree of dilatation above this level (Fig. 2). There were no irregularities in the outline of the esophagus to suggest the presence of a neoplasm. Only a very small amount of barium trickled through into the stomach during the course of the examination.

The patient continued to improve clinically, and serial roentgenograms of the chest showed progressive clearing of the area of infiltration and gradual disappearance of the cavity. Antispasmodics were administered but in spite of these she continued to have difficulty in swallowing. On May 17, esophagoscopy was performed and a careful examination of the entire esophagus revealed no evidence of an organic legion. Esophageal bouginage was recommended and carried out.

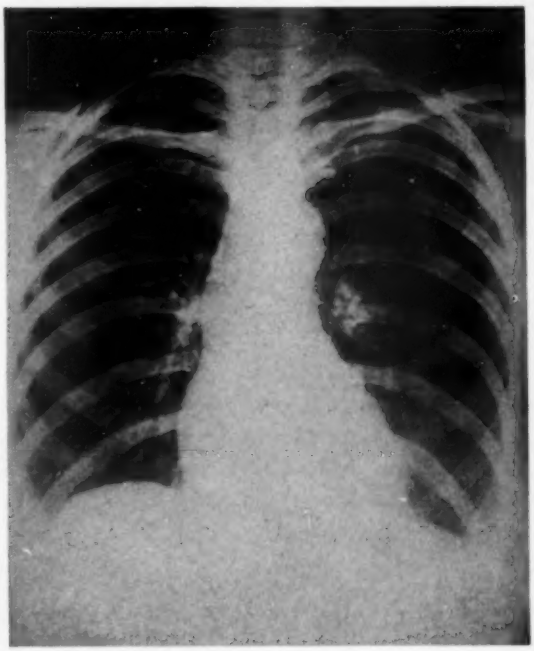

Fig. 3. Case 1. Roentgenogram of the chest taken two days before discharge. The abscess has healed and only minimal fibrosis remains.

At the time of discharge on June 24, 1939, the patient was entirely asymptomatic as regards the respiratory tract and a roentgenogram of her chest dated June 22, 1939, was normal except for the presence of minimal fibrosis at the site of the previous area of disease (Fig. 3).

Case II. E. Y., white male, aged fifty-eight, was admitted to the hospital on August 28,

1941, complaining of cough and expectoration which had developed in February, 1941, in the course of an upper respiratory infection, and of shortness of breath on exertion which had its onset in March. In June, 1941, wheezing became apparent, and he entered a tuberculosis sanatorium for observation. A roentgenogram of the chest taken at the sanatorium showed some evidence of pulmonary infiltration, but after a few weeks of hospitalization he was discharged as non-tuberculous. The patient also complained of difficulty in swallowing both fluids and solid food, stating that he would get a sense of "filling up in the throat" and often became nauseated. He was rather vague as to the exact duration of his dysphagia but it apparently dated back at least six months. The past history was significant in that he had bronchopneumonia in 1921, 1930 and in the fall of 1940. The patient had lost 19 pounds in weight during the six months preceding admission to the hospital.

On physical examination the patient appeared slightly dyspneic but otherwise comfortable and not acutely ill. His state of nutrition was fair. The thorax showed a deep anteroposterior diameter and rhonchi were present throughout both lung fields. The rest of the physical examination was negative except for the presence of a hydrocele on the left.

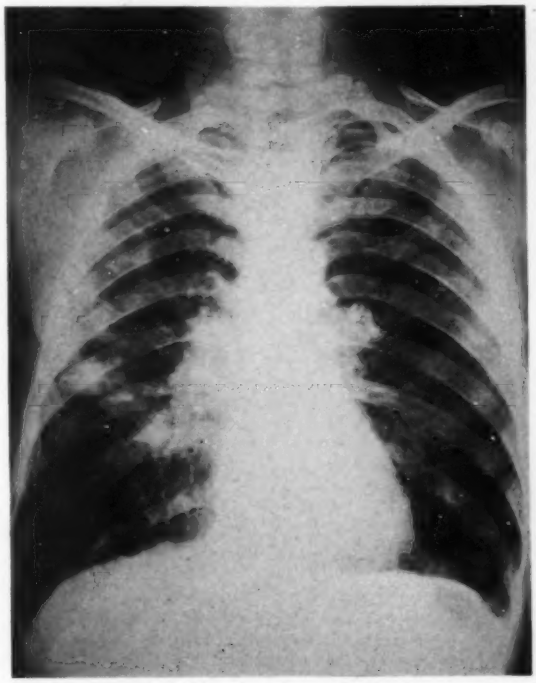

FIG. 4. Case II. Roentgenogram of the chest taken on admission. Note the scattered small areas of infiltration, especially well seen on the right.

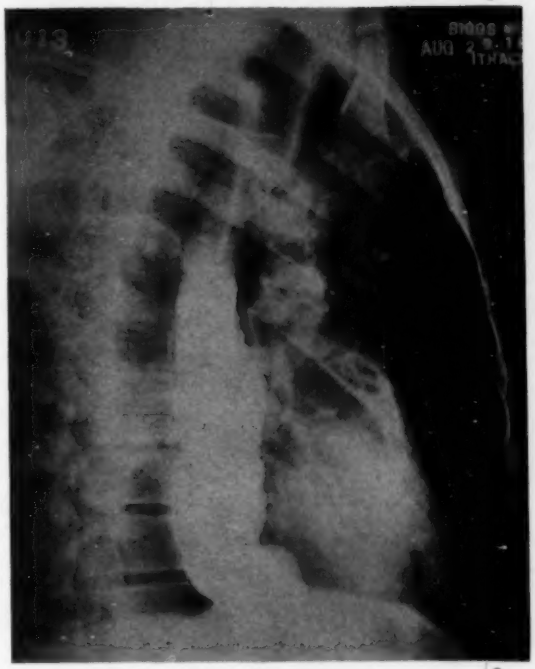

FIG. 5. Case II. Appearance of the esophagus approximately fifteen minutes after the ingestion of barium.

Laboratory examination revealed a normal blood count and a negative blood Wassermann. Urinalysis revealed the presence of a few hyaline and granular casts. Examinations of the sputum were microscopically negative for acid-fast bacilli and later the absence of tubercle bacilli was confirmed by cultural studies.

The clinical course in the hospital was marked by the absence of fever and the difficulty which the patient experienced in swallowing. On one occasion, he vomited soon after eating.

A roentgenogram of the chest taken on admission (Fig. 4) showed a few small mottled areas involving chiefly the mid-zone of the right lung at the level of the second interspace and at the level of the fifth anterior rib. Roentgenological examination of the esophagus revealed that the lower end tapered down to a fine point, but was free from any irregularity in contour (Fig. 5). In a period of roentgenoscopic observation of approximately ten minutes none of the barium entered the stomach. The examination

FIG. 6. Case III. Roentgenogram of the chest taken on admission to the hospital. Note the extensive infiltration in both lungs and the marked widening of the mediastinal shadows.

was repeated after the patient had been atropinized for four days and at this time there was still evidence of dilatation of the esophagus and spasm at the cardia but some barium was seen to enter the stomach.

On September 8 the patient was esophagoscoped and the esophagus was found to be smooth, dilated in its lower half, and filled with liquid contents and old food particles. Nowhere on the wall was there any evidence of neoplasm or ulceration. The cardia was passed without difficulty.

A second roentgenogram of the chest on September 15 showed some clearing in the areas of infiltration previously noted. Difficulty in swallowing persisted, however.

Esophageal bouginage was recommended and the patient was discharged at his request in order that he could obtain this form of therapy in the city from which he came.

Case III. H. D., white male, aged thirty-nine, was admitted to the hospital on June 2, 1942, with the chief complaint of cough, expectoration and ease of fatigue. The onset of these symptoms dated back to October, 1940, at which time the cough was minimal and the expectoration consisted of small amounts of mucopurulent material. One year later fatigue on exertion had its onset. One month before admission the fatigue became extreme and he began to suffer from dyspnea and vague symptoms of indigestion. During the month preceding hospitalization he lost 11 pounds in weight. On May 25, 1942, he first sought medical advice and a roentgenogram of the chest taken at that time, at another hospital, revealed changes which were thought to be suggestive of tuberculosis. The sputum, however, was found to be negative for acid-fast bacilli. The patient gave no history of chest pain or hemoptysis.

The past and family history, as first elicited, was not significant. Later developments, however, prompted a re-study of the past history and, on close questioning, the patient admitted that in 1923 he had had cardiospasm and had been treated by esophageal bouginage. He had attributed no importance to this episode, however, and since he had had no recurrences, he had "practically forgotten about it."

The patient appeared to be chronically ill and coughed occasionally during the course of the examination. The only positive findings related to the right lung field. Here there was slight impairment of the percussion note from the apex to the third rib, and the breath sounds were bronchovesicular in character. There was also a definite increase in vocal and tactile fremitus over the area of dullness but no râles were heard. Laboratory study revealed an erythrocyte count of 4.4 million cells with 13.2 grams of hemoglobin per 100 cc. and a leukocyte count of 14,600 cells with 80 per cent neutrophiles, 14 per cent lymphocytes, 3 per cent monocytes and 3 per cent eosinophiles. Urinalysis and Wassermann reaction were negative. The sputum was repeatedly negative for acid-fast bacilli and was of interest in that it routinely separated within a few minutes after collection into three layers, the upper of which was oily in appearance and consistency, and stained red with sudan III.

A roentgenogram of the chest (Fig. 6) revealed evidence of feathery infiltration throughout both lungs. In addition, a dense shadow with a sharply demarcated lateral border and a moth-eaten appearance was found extending from the apex to the base and involving the inner zone of the right lung. Bucky roentgenograms in the posteroanterior and lateral positions were then taken and these showed the

mass to lie anterior to the dorsal spine and to be not homogeneously dense but presenting a mosaic appearance with alternating small round areas of increased and decreased density.

An esophageal examination was carried out next and it was soon evident that there was a large mass of impacted food in a greatly dilated esophagus (Fig. 7, 8 and 9). At this time only an insignificant amount of barium was seen to enter the stomach.

Fig. 7. Case III. After the ingestion of barium the widening of the mediastinum is seen to be due to a markedly dilated esophagus containing impacted food.

The contents of the esophagus were evacuated by repeated lavage and roentgenographic study was renewed. Initial roentgenoscopy revealed a fluid level in the esophagus at about the height of the ninth dorsal vertebra. Barium collected at the bottom of the esophagus and none passed into the stomach until one full glass of the opaque material had been ingested. By this time the fluid level in the esophagus had reached the fourth dorsal spine and the barium was then seen to flow slowly into the stomach (Fig. 9). An hour later approximately one-half of the opaque material originally ingested had passed into the stomach, and two hours later at least 75 per cent of the barium was in the stom-

Fig. 8. Case III. Same as Figure 7. Lateral view.

Fig. 9. Case III. Barium in the esophagus and stomach, showing the relationship of these two structures. Note the marked widening and displacement of the esophagus and the large area of spasm at the distal end of the esophagus.

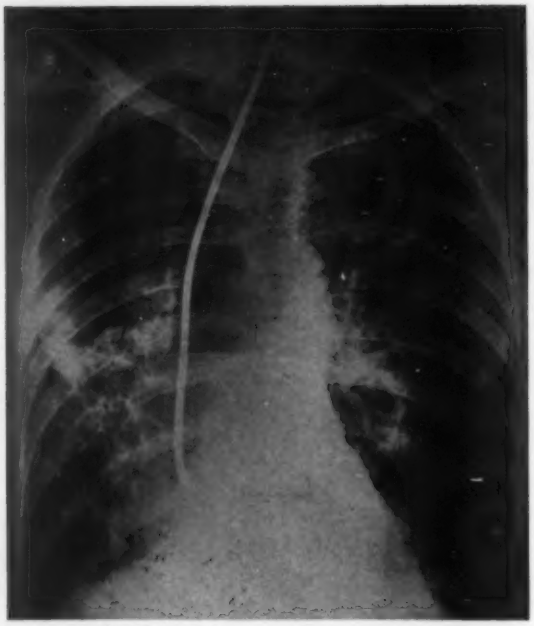

FIG. 10. Case III. The esophagus has been evacuated by repeated lavage but the spasm persists as shown by the fluid level and the failure of the Rehfuss tube to enter the stomach.

ach but the esophagus still contained considerable fluid and barium.

A bronchoscopy was performed and revealed the posterior wall of the trachea to bulge inward. At scattered points in the airways there were accumulations of thick exudate which in all instances could be brushed away by sponge or removed by suction, the underlying mucosa appearing normal. Histopathological examination of some of the material obtained by bronchoscopic suction showed chronic inflammatory exudate containing striated muscle fragments, probably the remains of aspirated meat particles.

Esophagoscopy revealed a greatly dilated esophagus with smooth walls and no evidence of ulceration. The stomach was entered without difficulty and no areas of ulceration, stricture or neoplasm were encountered at the cardia.

Examination of the colon by barium was made to rule out the possibility of a co-existent megacolon even though the available data pointed to cardiospasm as the basis of the esophageal dilatation. This examination revealed a normal colon.

Repeated attempts were made to pass a Rehfuss tube into the stomach so that small frequent feedings could be administered, but whenever the patient was checked roentgenoscopically it was found that the tube had coiled in the esophagus and that considerable fluid was present in this viscus (Fig. 10).

SUMMARY

Cardiospasm may result in pulmonary suppuration if the stagnant esophageal contents are aspirated. Three cases of this type are reported.

I wish to express my thanks to Dr. Clarence F. Graham for suggestions in the preparation of this paper.

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RIB FRACTURES IN ATYPICAL PNEUMONIA

By MAJOR ROLFE M. HARVEY
Medical Corps, Army of the United States

INTRODUCTION

DURING the course of an epidemic of the so-called virus or atypical pneumonia during the winter of 1942–1943, several instances of fractured ribs were noted in routine chest examinations. Many of these fractures were not detected at the time of the first examination and their presence was not appreciated until the subsequent development of callus formation on serial examinations of the chest to observe the progress of the pneumonia. A review of the current literature on atypical pneumonia did not reveal any previous description of the occurrence of rib fractures and for this reason it was thought desirable to bring this complication to the attention of roentgenologists in particular.

HISTORY

The first case of rib fracture from indirect violence was reported by Graves[5] in 1833, according to Richardson.[13] Gurlt,[6] in 1860, collected 14 cases of spontaneous fracture of ribs following coughing. Tunis[16] in 1890, collected 38 cases of indirect rib fractures, 25 of which followed coughing. He noted that those ribs to which the diaphragm is attached were most commonly fractured and that the fractures were usually in the middle or anterior third of the ribs. Both he and Seilin[15] drew attention to one fact, that the fractures most commonly occurred on the left side in the lower six ribs.

In 1924, Palfrey,[11] in an article on rib fractures by muscular action, mentions several cases seen during an epidemic of severe tracheitis. These cases were encountered during World War I by the 22nd General Hospital, which was staffed by the Harvard Unit. Among the instances of rib fractures occurring following coughing in tuberculous patients are those described by Parenti,[12] Webb and Gilbert,[17] Howson,[8] and Richardson.[13] Richardson described 20 cases of rib fracture associated with cough in a group of 1,903 patients in a tuberculosis sanatorium, and 10 additional cases in outpatients. Twenty-four of this group of cases had pulmonary tuberculosis, 3 had silicosis and tuberculosis, and 3 had chronic bronchitis.

Oechsli[10] summarized the literature in 1936 and reported 12 additional cases of rib fractures occurring in 2,000 admissions to a tuberculosis sanatorium. In all but one case the fractured ribs occurred in patients with far advanced tuberculosis. He described all fractures occurring in a line extending 4 cm. from the costochondral junction of the fourth rib obliquely caudad and laterally to the ninth rib in the mid-axillary line. This line corresponds to the attachment of the obliquus externus abdominis where it interdigitates with the serratus anterior muscle. He reasoned that the fractures were probably due to the opposing forces of these groups of muscles.

Sabbione[14] studied the incidence of rib fractures in pulmonary tuberculosis by reviewing 10,304 roentgenograms on 4,570 patients and discovered 19 cases, usually in older patients with advanced tuberculosis. He thought that the fractures were due to decalcification of the bones secondary to pulmonary tuberculosis.

Knoepp[9], in 1941, reported a series of 917 fractures of the ribs occurring in 386 patients. Fifty-seven of these fractures were due to coughing or sneezing and of these 57, four occurred in patients with pneumonia. This is the only direct reference found in the literature to fractured ribs actually associated with pneumonia.

Atkinson[1] and Halliwell[7] reported cases occurring in patients convalescing from influenza. Breidenbach[2] states that "muscle violence is a more common cause of fractured ribs than is usually thought. It is

commonly reported in tuberculosis resulting from violent coughing." Brewster[3] reported a case of fractured rib occurring in a patient who coughed violently after choking while eating a walnut. Edgecombe[4] reported a case of fractured rib occurring from cough in a case of whooping cough. He reported that the bones of the patient in this case showed some decalcification.

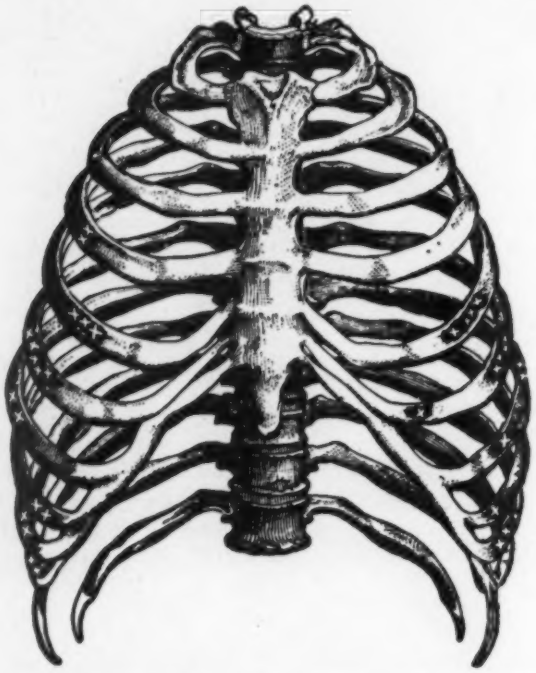

FIG. 1. A sketch of the bony thorax to illustrate the site of fractures in the cases reported. Each (x) indicates the site of a fracture.

Most of the standard texts on surgery mention the possibility of the occurrence of rib fractures from indirect violence such as coughing. None of the standard textbooks of medicine describe fractured ribs as a possible complication of pneumonia. As stated in the introduction, the occurrence of spontaneous rib fractures has not been described in any of the recent literature on atypical pneumonias.

METHOD OF STUDY

A consecutive series of 500 cases of atypical pneumonia occurring in a station hospital during the winter of 1942–1943 was reviewed. Nineteen of these patients had evidence of recent rib fractures. In 1 of these patients a definite history of trauma was elicited, but in all other cases trauma was excluded as a possible etiologic factor in the production of the fractures by careful questioning of the patients. Omitting the case with the definite history of injury the incidence of rib fractures in this series of cases was 3.6 per cent. A large percentage of these fractures was missed at the time of the original examination. On serial examination, during the observation of the course of the pneumonia, a fracture was commonly noted following development of callus. In these cases, a review of the original roentgenogram would usually disclose a definite fracture line. The appearance of the fracture lines and the subsequent development of callus left no doubt as to the fracture having occurred recently.

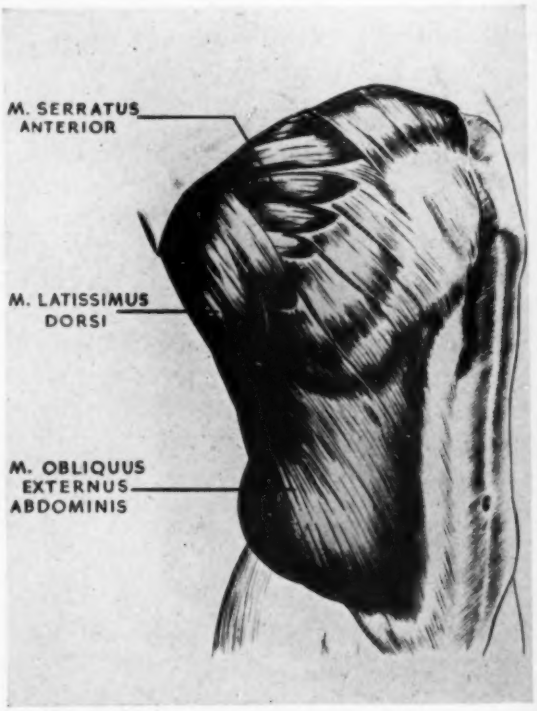

FIG. 2. A drawing of the interdigitations of the serratus anterior, latissimus dorsi and obliquus externus abdominis muscles to show the reason for the location of the fractures at the level of the insertion of these muscle groups. Compare this figure with Figure 1.

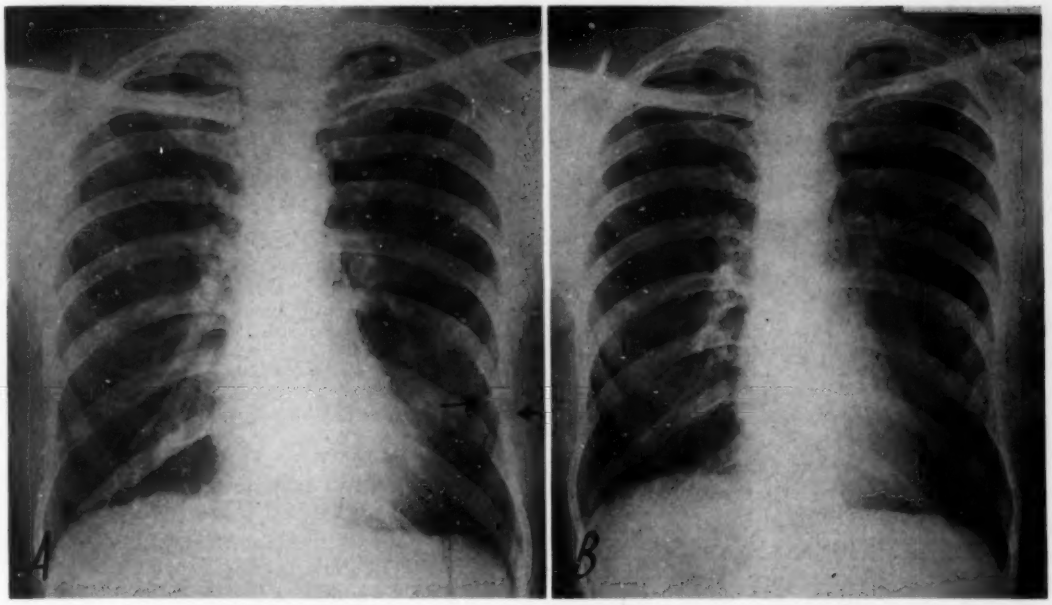

FIG. 3. Case 1. *A*, roentgenogram taken on January 22, 1943, shows an area of pneumonia at left base adjacent to left border of heart. Fractures of the sixth and seventh ribs on the left side are indicated by arrows. The fracture line indicated by the arrow in the right sixth rib could be seen on the roentgenogram. *B*, roentgenogram taken on March 25, 1943. After resolution of the pneumonia, dense callus formation can be seen about the fractures of the fifth, sixth and seventh ribs on the left side anteriorly and about the sixth rib on the right side near its anterior extremity and the fifth rib on the right in the anterior axillary line.

In several of the cases the fractures were quite apparent on review but at the time of the original examination the attention of the examiner was centered on the more obvious inflammatory process in the lungs. In 10 of the 18 cases the fractures were not recognized until a routine review of the entire series was made in a definite search for them. As some of these fractures were obvious and all of them could have been detected on a careful study of the roentgenograms, it is felt that by calling the attention of other roentgenologists to this complication omission of the detection of these fractures may be avoided.

DESCRIPTION OF FRACTURES

Figure 1 shows the site of the 34 fractures which occurred in this series of 18 cases of atypical pneumonia. It will be noted that the fractures were almost invariably grouped in the region of the interdigitation of the muscle fibers of the serratus anterior and the obliquus externus abdominis muscles as shown in Figure 2. One patient had five fractures, 4 patients had three fractures, 4 patients had two fractures and the remaining 9 patients had one fracture. In 8 cases the fracture or fractures were on the right side, in 9 cases on the left side, and in the case with five fractured ribs the fractures were bilateral.

As shown in Figure 1, all fractures were in the anterior axillary or mid-axillary line. In the nineteenth case, in which there was a definite history of injury, the fractures were in the posterior portion of the ribs and were obviously due to direct violence. In 4 cases the rib fractures were on the opposite side of the chest from the pneumonic process and in the remaining cases the fractures were on the same side. The results in the series of cases lends credence to the argument of Oechsli[10] that the mechanism of the production of these fractures is due to the opposing forces of the serratus anterior and the obliquus externus abdominis muscles.

TYPE OF PNEUMONIA

All patients in this series had the type of pneumonia which has been described clinically and roentgenologically as the so-called atypical pneumonia. Sputum examinations showed the presence of hemolytic and nonhemolytic streptococci and *Micrococcus catarrhalis* and only occasionally pneumococci. The pneumonias in this series of rib fractures were all located at the bases on the left side in 7, on the right side in 4, and bilateral in 7 cases.

SUMMARY OF CASES

Case I (see Fig. 3). The age of the patient was forty-one. Date of admission, January 22, 1943.

Chief Complaint. Bilateral pleurisy and cough.

History of Present Illness. Patient caught severe cold en route to camp six weeks previously and has been coughing since that time. Coughing, lifting or twisting body causes pain along both costal margins.

Clinical Diagnosis. Acute myositis.

Roentgenological Diagnosis. Left-sided atypical pneumonia. Fractures of the left fifth and sixth ribs in the mid-axillary line, the left seventh rib in the axillary line and the right fifth and sixth ribs in the anterior axillary line.

Comment. This case had the greatest number of fractured ribs and coincidentally the greatest degree of chest pain.

Case II. The patient was aged forty-two. Date of admission, April 17, 1943.

Roentgenological Diagnosis. Right basal atypical pneumonia. Fracture of the left fourth rib in the anterior axillary line and the left seventh and eighth ribs in the axillary line.

Comment. This patient was psychotic and a satisfactory history was impossible. It was likewise impossible to make any evaluation of the patient's chest pain.

Case III. The age of the patient was thirty-five. Date of admission, March 19, 1943.

History of Present Illness. Patient had no complaints on admission but had had a cold five weeks prior to admission.

Roentgenological Diagnosis. Atypical pneumonia, right base, Fracture of the left sixth rib in the anterior axillary line.

Comment. This is 1 of 2 cases in this series admitted without complaints, although showing definite roentgen evidence of atypical pneumonia and rib fractures. It has been frequently noted that cases of atypical pneumonia are picked up on routine

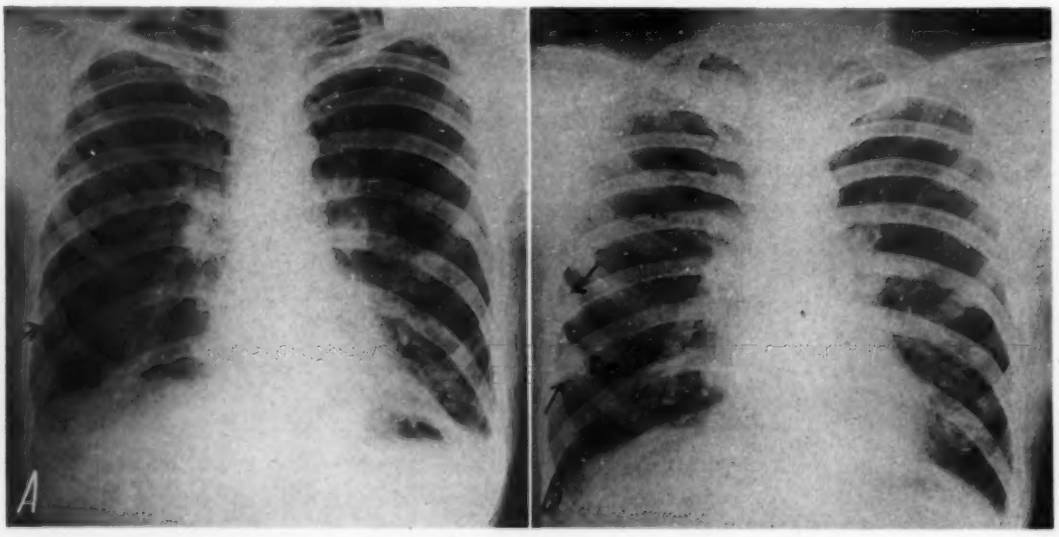

Fig. 4. Case VI. *A*, roentgenogram taken on November 13, 1942, shows bilateral basal pneumonitis with an incomplete fracture of the seventh rib on the right in the anterior axillary line as indicated by the arrow. *B*, roentgenogram taken on December 17, 1942, shows partial resolution of the pneumonitis with dense callus formation about fractures of the sixth and seventh ribs on the right as indicated by the arrow.

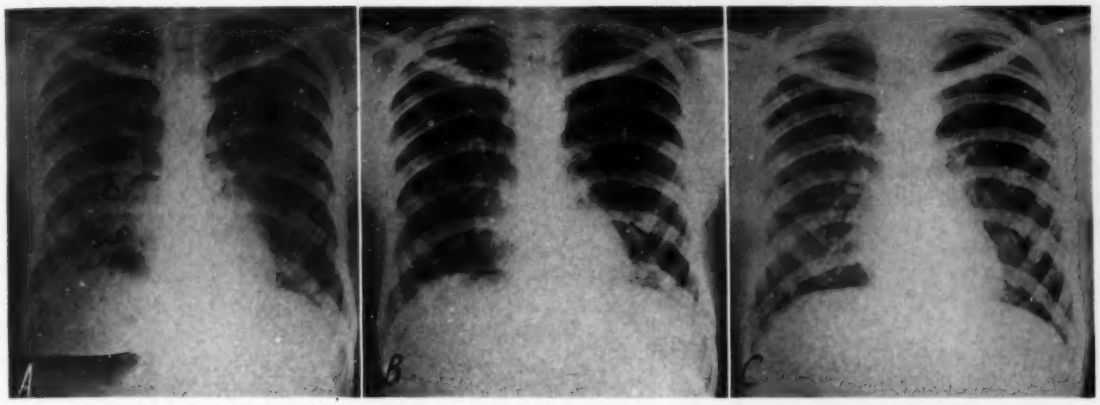

Fig. 5. Case VIII. *A*, roentgenogram taken on March 30, 1943, shows a bilateral atypical pneumonitis. No evidence of fractured ribs at this time. *B*, the pneumonitis is clearing on this examination which was made on April 12, 1943. There is an incomplete fracture of the fifth rib on the left side in the anterior axillary line as indicated by the arrow. *C*, roentgenogram taken on June 3, 1943, shows complete resolution of the pneumonia and moderate callus formation about the fractured rib.

examination in men who are apparently healthy and do not appear clinically to have a pneumonia.

Case V. Patient, aged thirty-one. Date of admission, April 2, 1943.

Chief Complaint. Pain in the chest, slight cough.

History of Present Illness. Pain in the side for one week, subsiding at time of admission. Slight pains in the right axilla on deep breathing. Patient complained occasionally of pain in the right chest for three weeks following admission. Sputum contained non-hemolytic streptococci and *Micrococcus catarrhalis*.

Roentgenological Diagnosis. Atypical pneumonia, left base. Fractures of the right fifth, sixth and seventh ribs in the axillary line.

Comment. This is 1 of the 4 cases where the rib fractures occurred on the opposite side from the pneumonia.

Case VI (see Fig. 4). Patient, aged twenty-two. Date of admission, November 17, 1942.

Chief Complaint. Cough and pain in the chest.

History. Cough present for ten days accompanied by slight chest gain. Pneumonia discovered on routine roentgenogram. Roentgenological diagnosis was bilateral atypical pneumonia. Fractures of the sixth and seventh ribs, right axillary line.

Case VIII (see Fig. 5). Patient, aged nineteen. Date of admission, March 15, 1943.

Chief Complaint. Patient has had frequent colds, chronic productive cough, pain in the left lower chest. Has had frequent admission to the hospital for these complaints. Roentgenological diagnosis was bilateral basal atypical pneumonia. Fracture of fifth rib in the left anterior axillary line.

Case XI. Patient, aged nineteen. Date of admission, February 27, 1943.

Chief Complaint. Patient has had no complaints. Pneumonia discovered on routine chest roentgenogram.

Roentgenological Diagnosis. Atypical pneumonia, left base. Fracture, left sixth rib, anterior axillary line.

Comment. This patient had absolutely no complaints referable to his pneumonia or his rib fracture, and no complaints could be elicited following discovery of these chest lesions. It is remarkable how little symptomatology may be present with a fairly extensive degree of atypical pneumonia. The frequency of the discovery of areas of atypical pneumonia on a routine chest survey of apparently healthy individuals is probably due to delayed resolution. It has been noted that involvement of the lungs persists for some time after patients are clinically well in cases of atypical pneumonia.

Case XVII (see Fig. 6). Patient, aged twenty-six. Date of admission, April 14, 1943.

Chief Complaint. Pain in the chest, dry cough.

History. Severe pain in the right chest on coughing and deep breathing, tenderness in the right chest. Chest pain persisted for one month following admission requiring frequent administration of codeine. Sputum contained hemolytic streptococci.

Roentgenological Diagnosis. Moderate bilatlateral basal atypical pneumonia. Fracture sixth rib, right anterior axillary line.

Case xviii. Patient, aged thirty-one. Date of admission, February 17, 1943.

Chief Complaint. Pain in the chest, cough, chills.

History. Persistent left-sided chest pain for two months. Sputum contained hemolytic and non-hemolytic streptococci and *Micrococcus catarrhalis.*

Roentgenological Diagnosis. Bilateral basal atypical pneumonia. Fracture, fifth rib, right anterior axillary line.

The following case is not included in the series of fractures due to indirect violence since the patient gave a definite history of injury.

Case xix. Patient, aged forty-one. Date of admission, January 26, 1943.

History. Patient was sent in following routine chest roentgen examination for discharge from Army. Stated he was carrying another soldier on his back two weeks prior to admission when he collided with another man. Had sharp pain in right chest below the angle of the scapula. Has been in camp for one month and has had a cold, cough and expectoration.

Roentgenological Diagnosis. Right basal atypical pneumonia. Fracture of the sixth and seventh ribs on the right near their costovertebral junctions.

It will be noted from reviewing the roentgenograms of these cases that most of the pneumonic processes were slight in extent. No cases of rib fractures were noted in frank lobar pneumonia. The fractures all healed rapidly. In no case was there any apparent lack of calcium in the bones which could account for the occurrence of the fractures.

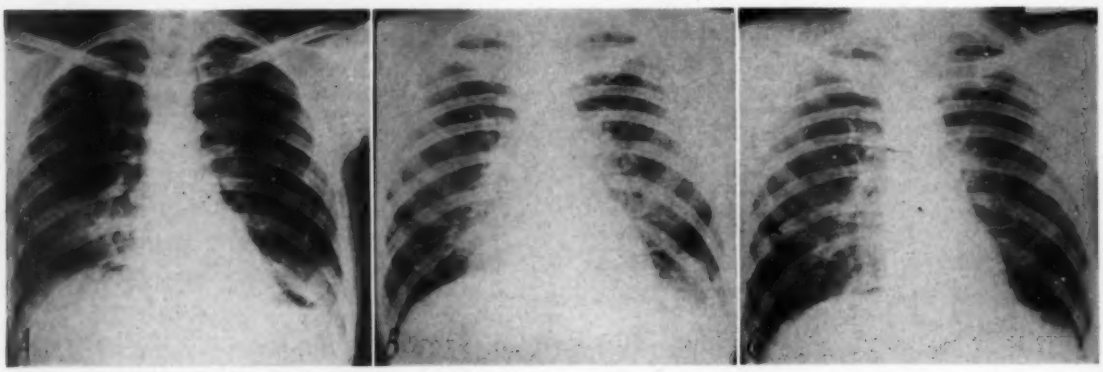

Fig. 6. Case xvii. *A*, roentgenogram taken on April 20, 1943, shows bilateral basal atypical pneumonia. No evidence of rib fracture at this time. *B*, roentgenogram taken on April 30, 1943, shows an incomplete fracture in the sixth rib on the right as indicated by the arrow. Some resolution of the pneumonic processes has occurred. *C*, roentgenogram taken on May 26, 1943, shows complete resolution of the pneumonic processes. There is now definite evidence of callus formation about the fractured right sixth rib as indicated by the arrow.

SUMMARY

Eighteen cases of fractured ribs were noted in a review of five hundred consecutive cases of atypical pneumonia. In 50 per cent of these cases the fractures were multiple, in four cases the fractures occurred on the opposite side from the pneumonia. All fractures occurred in the anterior axillary or axillary line. The reason for this has been postulated as due to the opposing forces of the serratus anterior and externus obliquus abdominis muscles as shown in Figure 2. The occurrence of rib fractures was not re-

lated to the severity of the pneumonia. Associated with atypical pneumonias is a severe, dry, irritating cough which is probably a factor in the production of the fractures. Excessive chest pain occurring in cases of atypical pneumonia should direct the search of the roentgenologist toward this complication. The attention of roentgenologists is directed to this complication of atypical pneumonia in order that the fractures may not be overlooked when study is centered on obvious inflammatory processes. This happened in many of the cases in the present series. This complication may explain many supposed cases of pleurisy in atypical pneumonia.

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CONGENITAL ABSENCE OF RIBS*

By BERNARD N. E. COHN, M.D.
DENVER, COLORADO

CONGENITAL absence of a single rib is an infrequent occurrence. Congenital aplasia of two or more consecutive ribs unilaterally is a rarity. Such a deformity may be present either without other anomalies or it is found more often in conjunction with defects of the pectoral muscles, vertebrae, or position of the scapula. Any combination of these aberrations may occur in the same individual.

The reports [8,16,18,19,25,30] recorded prior to the era of roentgenography, with the exceptions of the autopsied cases of Gripat,[11] Vrolick,[31] and Ardouin and Kirmisson,[3] are open to question. Following the advent of the x-ray the first proved case of congenital absence of a rib was reported by Freund.[7] The papers which have appeared since 1900 may be classified into three groups: (1) those in which one rib is missing unilaterally or bilaterally;[1,2,6,9,12,13,17,20,21,26] (2) those wherein two or more consecutive ribs are lacking on the same side;[5,12,15,21,22,23,27,28] (3) a miscellaneous group which does not fit either of the foregoing classifications.[10,14,21,26] The most common anomaly is contained in the first group.

ILLUSTRATIVE CASES

Absence of One Rib; Congenital Scoliosis

CASE I (No. 38-10204). White male who has been seen in this Clinic since the age of two. Spontaneous eight month birth. No history of congenital malformations in the family. The physical examination was essentially negative with the exception of congenital scoliosis with convexity to the left.

Roentgenographic examination revealed twelve ribs on the right, eleven on the left (Fig. 1). The sixth left rib is absent. There is wide separation of the fourth, fifth and sixth left ribs. The third and fourth thoracic vertebrae are wedge-shaped. Scoliosis with the apex of the curve to the left is present.

Comment. The absence of the left sixth rib does not correspond to the site of the wedge-shaped vertebra. The sixth thoracic vertebra appears essentially normal in size and shape.

Absence of Two Consecutive Ribs Unilaterally; Scoliosis; Dextrocardia

CASE II (No. 49,686). White female, aged eight months. No history of congenital abnormalities in the family. Spontaneous birth. Physical examination revealed a healthy child who was slightly underweight. The left thoracic wall bulged noticeably. Palpation of this area failed to reveal the presence of ribs covering the defect. A protuberance of the left anterior thoracic cage was evident.

Roentgen examination showed twelve normal ribs on the right (Fig. 2). There are ten ribs on the left, the seventh and eighth being absent. The transverse processes of the corresponding vertebrae are enlarged, and appear to have fused into one mass. The size and shape of all the thoracic vertebrae appear normal. A left thoracic scoliosis with the apex of the curve at the level of the sixth to the eighth bodies is present. The inferior angle of the left scapula is situated one rib higher than the right. The air shadow on the right extends to the ninth rib; on the left it is not observed beyond the sixth rib. The heart shadow is entirely confined within the right thorax.

Comment. This case is of special interest because there is complete aplasia of two ribs without apparent abnormalities in the shape of the vertebrae. A herniation of the thoracic wall is present. The dextrocardia is probably upon a mechanical basis, instead of an anomaly as is found in a normal thorax. From a roentgenographic standpoint the area of the left thoracic cage does not seem adequate to contain both the lung and heart.

Absence of Two Consecutive Ribs Unilaterally; Hemivertebra

CASE III (No. 39-9926). White female who was first seen at the age of six months. Cesarean section at full term. She is the third living child

* From the Department of Orthopaedic Surgery (Service of Arthur Steindler, M.D.), The State University of Iowa Hospitals, Iowa City, Iowa.

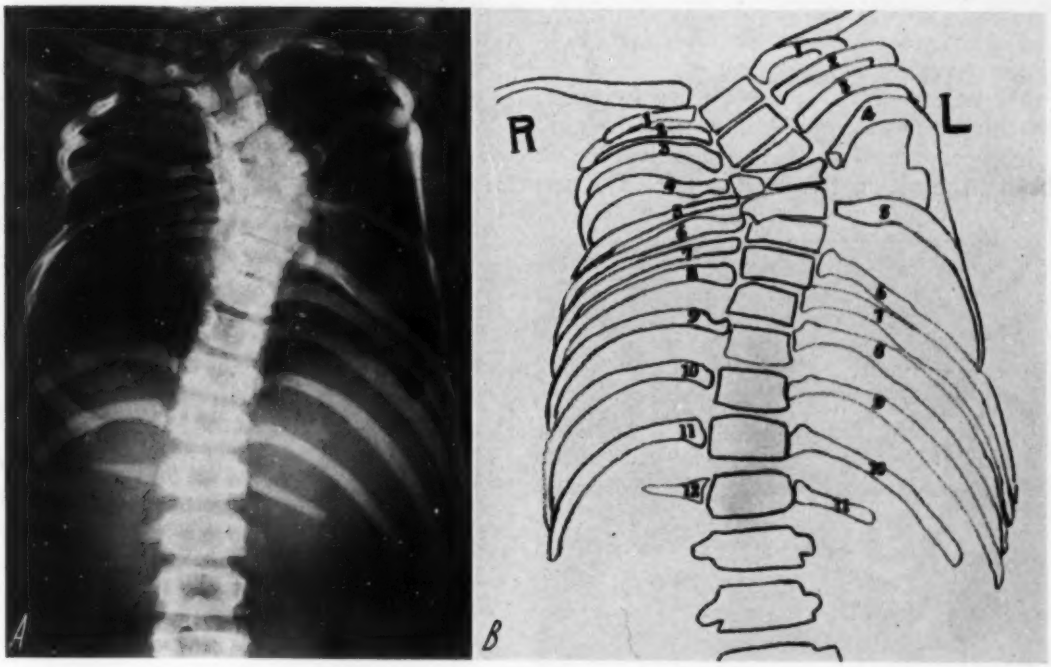

Fig. 1. *A*, roentgenogram showing absence of left sixth rib. See text.
B, tracing of roentgenogram shown in *A*.

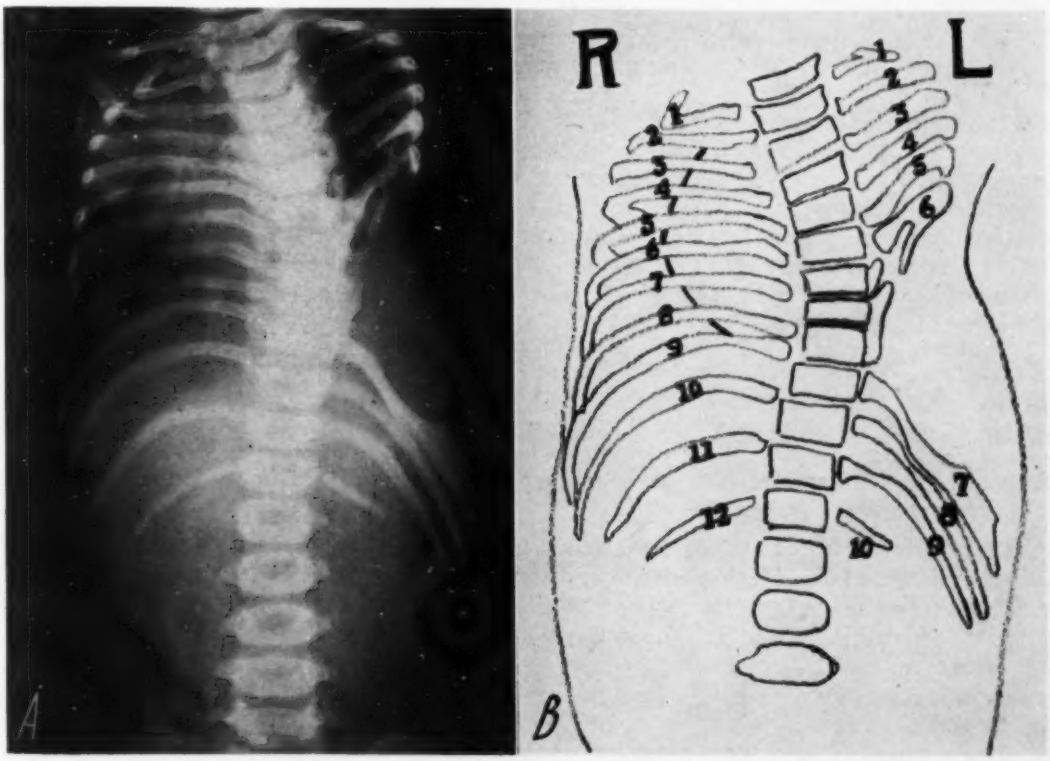

Fig. 2. *A*, roentgenogram showing absence of left seventh and eighth ribs. See text.
B, tracing of roentgenogram shown in *A*.

of normal parents; the first was a hydrocephalic, and the second was normal. Physical examination revealed a marked congenital scoliosis with convexity to the right. No other congenital abnormalities were present.

Roentgenographic examination showed twelve ribs on the right, ten on the left. The left ribs appear normal in size and shape. The right second, third and fourth ribs are absent. The fifth and sixth ribs are fused into one mass. There is malformation of the first to the third vertebral bodies, inclusive. The fourth thoracic vertebra is a definite hemivertebra. A cervical rib on the right is noted. The position of the left

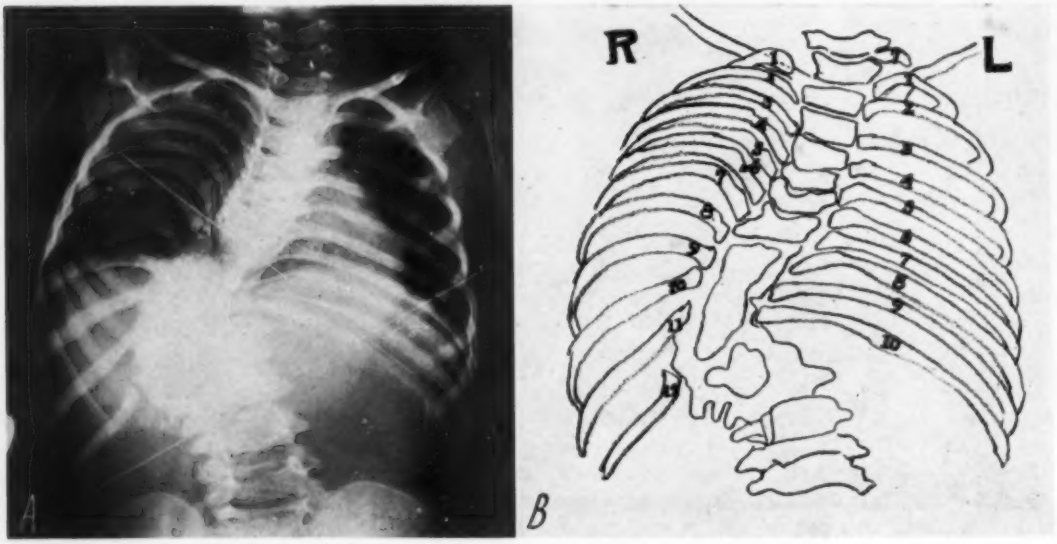

Fig. 3. *A*, roentgenogram showing absence of left eleventh and twelfth ribs. See text. *B*, tracing of roentgenogram shown in *A*.

eleventh and twelfth ribs are lacking (Fig. 3). There are no pronounced irregularities in the configuration of the ribs. Marked aberrations of the sixth thoracic to the third lumbar vertebrae, inclusive, are present, as manifested by hemivertebrae and spina bifida. An advanced thoracolumbar scoliosis with convexity to the right is noted.

Comment. The aplasia of the eleventh and twelfth ribs occurs at the site of marked congenital malformation of the vertebrae.

Absence of Three Consecutive Ribs Unilaterally; Hemivertebra; Sprengel's Scapula

Case iv (No. 40-9220). White female who has been followed in this Clinic since the age of six. Spontaneous full term birth. No history of congenital deformities in the family. On physical examination elevation of the right scapula, scoliosis and deformity of the right anterior thoracic wall were noted.

Roentgen examination revealed twelve ribs on the left, nine on the right (Fig. 4). The left scapula is normal; the right scapula is markedly elevated. Right thoracic scoliosis is present.

Comment. This case illustrates unilateral absence of ribs associated with congenital elevation of the scapula. Sprengel's scapula is not an infrequent associated deformity in these cases. The aplasia of the ribs occurs at the site of malformation of the vertebral bodies.

Absence of Ribs Bilaterally; Hemivertebra

Case v (No. 38-25230). White male who was first seen at the age of five. Full term, spontaneous delivery. He was the fourth child of normal parents. No history of congenital deformities in the family. In addition to congenital scoliosis, left talipes calcaneus and dislocation of the left hip were present.

Roentgenographic examination revealed ten ribs on the right, eleven on the left (Fig. 5). There are no severe aberrations in the size and shape of the ribs. The tenth rib on the left is

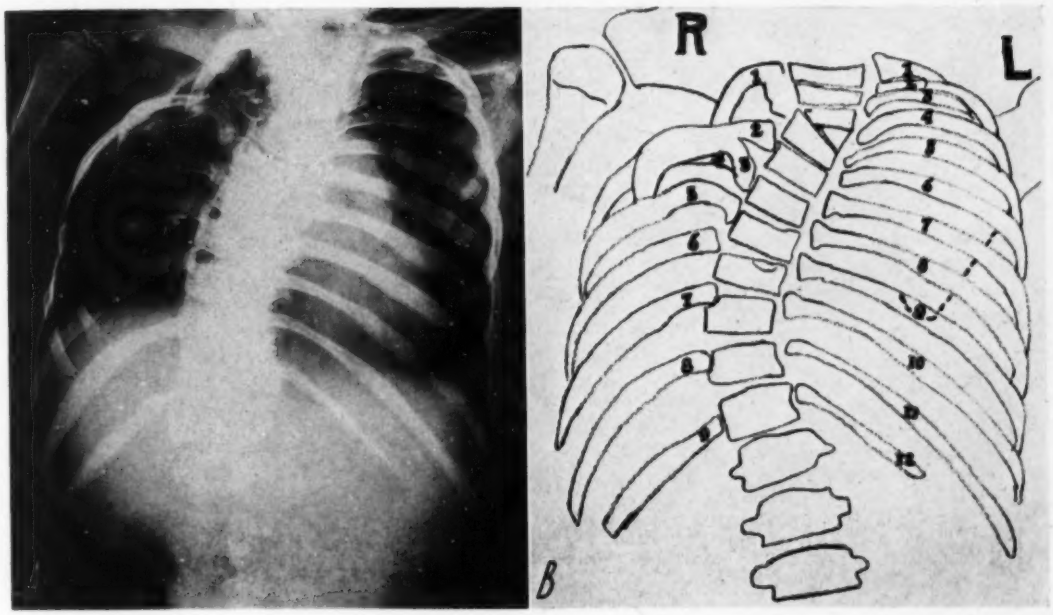

Fig. 4. *A*, roentgenogram showing nine ribs on right, twelve on left. See text.
B, tracing of roentgenogram shown in *A*.

attached to a hemivertebra. A mild left scoliosis with the apex at the level of the hemivertebra is present. There are five lumbar vertebrae.

Comment. This case falls into the category of the miscellaneous group of rib defects. In addition to aplasia of ribs, total suppression of the corresponding vertebrae is found.

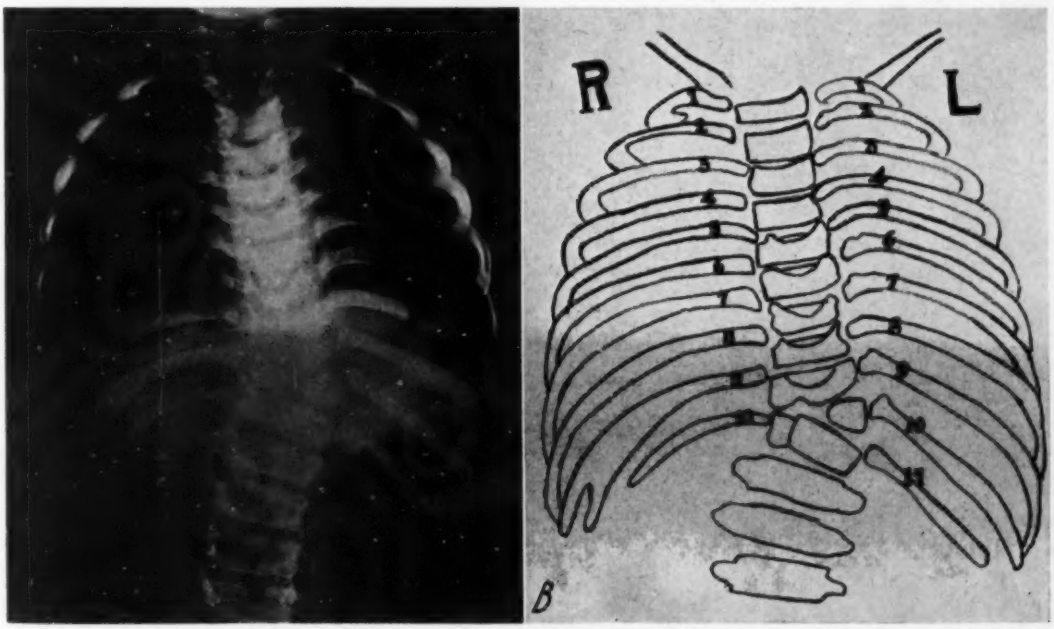

Fig. 5. *A*, roentgenogram showing ten ribs on right, eleven on left. See text.
B, tracing of roentgenogram shown in *A*.

DISCUSSION

The association of rib aplasia with defects of the vertebral body is explainable on the basis of embryology. The primordia of the definitive vertebrae are derived from the sclerotomic mesenchyme arranged in paired segmental masses alongside the notochord.[4] From each pair of primordia thus formed, growth takes place in three principal directions: (1) mesially, the cells surround the notochord and establish the vertebral body; (2) dorsally, flanking the neural tube, to form the vertebral arch; (3) ventrolaterally, to provide the costal processes from which the ribs originate. The denser portion alone sprouts off the processes that become the vertebral arch and the rib (Fig. 6).

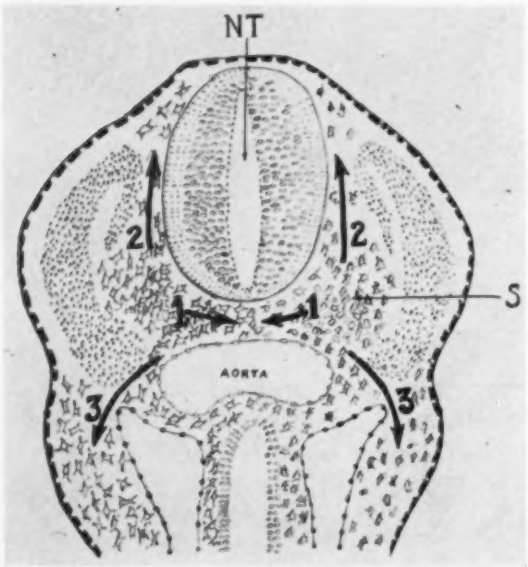

FIG. 6. Drawing showing differentiation of embryonic sclerotomic mass into various components of vertebra and ribs. (Modified after Arey.[4]) *NT*, neural tube; *S*, sclerotomic mass; *1*, direction of sclerotomic growth to form vertebral body; *2*, direction of growth to form vertebral arch; *3*, direction of growth to form costal processes from which ribs originate.

The intimacy of the primordium of a rib and its corresponding vertebra is thus clearly shown from an embryological standpoint. It is readily appreciated, therefore, that any factor which may operate to inhibit the growth of the primordium of a rib may at the same time interfere with the primordium of the vertebral body or arch. Because of the common origin, it is surprising that all cases of aplasia of ribs are not accompanied by hemivertebra, or vice versa.

Ritter and Eppinger[24] believed that defects of ribs were caused by the pressure of an arm against the thoracic cage due to the lack of amniotic fluid. This hypothesis was favored by Thomson[30] and Kienböck.[15] The mechanical modus operandi was considered because the arm could be placed in the hernial defect of the thoracic wall. It is impossible to conceive that an arm could remain in one position sufficiently long during intrauterine life to suppress development of ribs, either partially of totally. Moreover, the frequent association of rib defects with vertebral anomalies entirely vitiates this hypothesis. The theory of amniotic adhesions is likewise highly untenable.

Stockard,[29] who worked with the eggs of the *Fundulus*, has advanced an explanation for malformation. He claims that there are critical moments in the development of every organ or part which are characterized by rapid cell multiplication. At such times this particular proliferating region is dominant, and may even exert a depressing influence over the growth of other parts. If this favorable moment for differentiation is not taken advantage of, the transient supremacy of the part is lost, and it in turn submits to depression by other parts assuming their dormant periods. The result is a reduced or imperfectly formed region which, having missed its opportunity, is never able to express itself completely or perfectly in competition with other parts now arrived at similar states of preferment. Each organ or part, therefore, not only originates from a definite primordium but also arises at a very definite moment that must be utilized then, if ever.

According to Stockard's theory[29] the most frequent factors which operate to evoke defects are changes in the conditions

of moisture, temperature, and oxygen supply. This theory appears to be the most tenable for the explanation of aplasia of ribs and associated vertebral anomalies when present.

SUMMARY

Complete absence of ribs may be divided into three groups: (1) absence of one rib unilaterally or bilaterally; (2) aplasia of two or more ribs unilaterally; (3) a miscellaneous group. Any of these categories may be associated with anomalies of the vertebral body. Illustrative cases of each category are recorded.

The embryology of the rib and vertebral body is presented. The theories of etiology of complete aplasia of ribs are discussed.

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ROUTINE CHEST ROENTGENOGRAPHY ON NEGRO INDUCTEES AT FORT BENNING, GEORGIA

By LIEUTENANT COLONEL E. R. BOWIE
Medical Corps, Army of the Untied States
and
FIRST LIEUTENANT H. G. JACOBSON
Medical Corps, Army of the United States

IN THIS presentation we are reporting the results of an analysis of routine chest examinations made on Negro inductees at the Armed Forces Induction Station, Fort Benning, Georgia. These statistics cover a period of thirty-one months.

The total number of cases examined is 102,241. Of these, 6,261 were examined in an eight month period, and these examinations were made on single acetate 14 by 17 inch films (stereoscopic pairs were used when deemed necessary). During the remaining twenty-three months 95,986 cases were examined with an Army photoroentgen unit, using 4 by 5 inch stereoscopic films. In those cases where a conclusive diagnostic statement could not be made, either a single or a stereoscopic pair of 14 by 17 inch films was obtained and, rarely, lateral films were made. Thus 93.8 per cent of our cases were examined routinely with the photoroentgen unit (Table 1).

TABLE I

TOTAL NUMBER OF CASES EXAMINED: 102,247

	No. of cases	Percentage
Standard 14×17 inch film.....	6,261	6.2
Photoroentgen 4×5 inch stereo pair.....	95,986	93.8

As indicated above, all cases examined were Negro males, having an age range usually seen in any Army induction station. All individuals were given routine roentgenographic chest examinations. These Negro inductees came almost entirely from Alabama and Georgia with a scattered few claiming other Southern states as their homes. We consider it unnecessary to discuss the method of operation of the photoroentgen unit used since this subject has been more than adequately discussed by de Lorimier,[1,2] Ehrlich, Schiller and Edwards,[3] and others. Interpretation of the roentgenograms was always carried out by an experienced roentgenologist. During the thirty-one month period covered by this study as many as six roentgenologists were used for film interpretation of the roentgenograms, but the great majority of the roentgenograms were diagnosed by one or two men.

Our criteria for acceptance or rejection on the basis of the chest roentgenogram are contained in MR 1-9.[4] We adhered most strictly to this set of rules.

We have attempted to divide our rejections into four large groups: (1) tuberculosis; (2) other lung diseases; (3) a miscellaneous group consisting of diseases of the thoracic cage, mediastinum, pleura, diaphragms, and dorsal spine; (4) abnormalities of the heart and great vessels.

In the first group it is seen (Table II) that there were 397 cases of active tuberculosis —activity being diagnosed on the presence

TABLE II

GROUP I. TUBERCULOUS LESIONS
(Disqualified)

Type of lesion	No. of cases	Percentage
Active tuberculosis.....	397	0.38
Tuberculous calcifications.....	338	0.33
Tuberculous infiltration—apparently fibrotic.....	126	0.12
Totals.....	861	0.83

of cavitation, tuberculous bronchopneumonia, etc. There were 338 cases of tuberculous calcification that could not be considered acceptable under MR 1-9, and 126 cases of tuberculous lesions that were apparently fibrotic and were disqualifying, since they occupied an area of lung tissue 5 sq. cm. or larger. This gives a total of 861 cases, or 0.83 per cent rejected because of pulmonary tuberculosis. But, in addition (see Table III) there were 1,308 cases, or 1.27 per cent, deferred for six months because of the presence of tuberculous infiltration—apparently fibrotic, and occupying an area of lung tissue less than 5 sq. cm. in size. Since 0.83 per cent of the total cases examined were rejected for pulmonary tuberculosis, and 1.27 per cent were deferred for at least six months, we had a total of 2,169 cases, or 2.1 per cent, that were rejected at the time of examination because of pulmonary tuberculosis. Theoretically, all of the 1,308 cases of Table III should have been returned for possible induction after six months, but, unfortunately, due to circumstances beyond our control, we were unable to obtain an exact statistical follow-up on this group. Our general impression is that approximately 60 per cent of this latter group was finally considered acceptable (fibrotic lesion less than 5 sq. cm. that showed no change over a period of six months). Therefore, instead of considering that 2.1 per cent were rejected for pulmonary tuberculosis we feel justified in assuming that the correct figure would be closer to 1.3 per cent (arrived at by subtracting 60 per cent of the 1,308 cases in Table III).

TABLE III

GROUP I(A). TUBERCULOUS LESIONS
(Deferred for 6 mo.)

Type of lesion	No. of cases	Percentage
Tuberculous infiltration—apparently fibrotic (less than 5 sq. cm.)	1,308	1.27

TABLE IV

GROUP II. OTHER LUNG DISEASES
(Disqualifying)

Pneumonia	418
Pneumoconiosis	21
Spontaneous pneumothorax	14
Cystic lung disease	12
Bronchiectasis	6
Pulmonary tumor	4
Emphysema	4
Pulmonary abscess	3
Atelectasis	1
Boeck's sarcoid	1
Total	484 or 0.47%

This figure of 1.3 per cent compares favorably with that found in other inductee series.[3,5] To us, this was somewhat surprising in view of the generally lower economic status of our group in comparison with most other series and, of course, the racial factor. We would have expected a higher incidence of pulmonary tuberculosis as cause for rejection.

The second group of rejections consists of ten various lung diseases, of which pneumonia is, by far, the largest component (see Table IV). We had the surprisingly large number of 418 cases of pneumonia of various types. This is a good deal higher inci-

TABLE V

GROUP III. MISCELLANEOUS GROUP, INCLUDING DISEASES OF THORACIC CAGE, MEDIASTINUM, PLEURA, DIAPHRAGM AND DORSAL SPINE
(Disqualifying)

Pleural change	168
Enlarged non-calcified hilar nodes	46
Scoliosis dorsal spine	40
Mediastinal tumor	9
Eventration of diaphragm	9
Abnormal diaphragmatic elevation—undetermined cause	7
Rib tumor	4
Hiatus hernia	3
Tuberculosis dorsal spine	1
Total	287 or 0.28%

dence of pneumonia than we have been able to find in any other comparable series. We had 21 cases of pneumoconiosis, most of whom came from coal mining towns in Alabama. The 14 cases of spontaneous pneumothorax simply re-affirmed our belief that this is not a rare disorder. There were 12 cases of cystic lung disease, 6 cases of bronchiectasis, and 4 cases each of pulmonary tumor and emphysema of a disqualifying nature. There were 3 cases of pulmonary abscess, and 1 case each of atelectasis and Boeck's sarcoid. The total in the second group is 484 cases, or 0.47 per cent.

TABLE VI

GROUP IV. ABNORMALITIES OF HEART AND GREAT VESSELS
(Disqualifying)

Cardiac abnormalities, i.e. enlargement and/or abnormal configuration	333
Diseases of aorta	84
Pericardial disease	2
Total	419 or 0.41%

The third large group is a miscellaneous one that consists of diseases of the thoracic cage, mediastinum, pleura, diaphragm and dorsal spine (see Table v). In this group there were 168 cases of pleural change to a disqualifying extent. There were 46 cases of enlarged hilar nodes—all noncalcified. Unquestionably, some of these were tuberculous in nature but we feel that a good part were lymphomas (Hodgkin's disease, lymphosarcoma, etc.). There were 40 cases of scoliosis of the dorsal spine with a curvature greater than that permitted under MR 1-9. There were 9 cases each of mediastinal tumor and eventration of the diaphragm, and 7 cases of abnormal diaphragmatic elevation of undetermined cause. There were 4 cases of rib tumor, 3 of hiatus hernia, and 1 of tuberculosis of the thoracic spine. The total in this group is 287 cases, or 0.28 per cent.

Group IV (see Table VI) deals with disqualifying abnormalities of the heart and great vessels. There were 333 cases of abnormalities of the heart as to size and/or configuration. There were 84 cases of disease of the aorta—aneurysm, arteriosclerotic or hypertensive changes. There were 2 cases of pericardial disease—both manifested by calcification of the pericardium. The total in Group IV is 419 cases, or 0.41 per cent.

The total number of rejections—that is, the summation of Groups I, II, III, and IV and subgroup (a) under Group I is 3,359 cases, or 3.2 per cent of the total number examined (see Table VII). Utilizing the same reasoning that we applied to Table III (above) the exact percentage of all those permanently rejected would be about 2.8 per cent of the total examined.

DISCUSSION

We believe that our series may be of some value since it is essentially a mass survey of Southern Negro males of Army age, presumably in good health, as far as their local communities were concerned. Statistically, this series is biometrically significant because of the large number of cases examined. This certainly must represent an adequate "sample."

TABLE VII

SUMMATION OF CASES REJECTED AND DEFERRED

Group	No. of cases	Percentage
I	861	0.83
I (a)	1,308	1.27
II	484	0.47
III	287	0.28
IV	419	0.41
Total	3,359	3.26

In looking over our figures we have been impressed by two facts: First, the incidence of rejectable cases of tuberculosis among this series of Negro inductees is apparently not significantly higher than in other series. One would expect a much higher incidence of rejectable tuberculosis in the Negro race and particularly among those Negroes of

the economic status found in Georgia and Alabama. Second, the number of ambulatory cases with pneumonia (418) is indeed striking. This means that 0.4 per cent of all our inductees had roentgenographic evidence of pneumonic infiltration at the time of examination. This is doubly surprising when one considers that these inductees presumably represented the healthy younger men of their respective communities. Why the Negro inductee in Georgia and Alabama should have such a relatively high incidence of pneumonic infiltration is difficult to understand. The answer may come with more large mass surveys in the future.

As noted above (Table 1) almost 94 per cent of our cases were examined by means of the Army photoroentgen unit, obtaining 4 by 5 inch stereoscopic films on each inductee, routinely. As we have also pointed out above, this was supplemented by standard acetate 14 by 17 inch films as considered necessary. As a general rule, we required supplemental films in no more than 1 per cent of the total cases examined. We believe that any detailed discussion as to the value and accuracy of 4 by 5 inch photoroentgenographic stereoscopic films is pointless. Those roentgenologists who have had any extensive experience with this method have absolutely no reservations as to the practicability and accuracy of this type of examination, particularly for large "screening" operations. Briefly, we are impressed by the following points: (1) quickness and ease in interpretation; (2) accuracy; (3) economy in use; (4) ease of handling, and (5) economy in storage.

All of these points have been adequately discussed by de Lorimier and others, yet we would like to stress points (1) and (2). We have found that it is much less tiring to interpret as many as 500 chest roentgenograms made by the photoroentgen unit than to "report on" only half as many single 14 by 17 inch chest roentgenograms. And we can do the 500 4 by 5 inch films more quickly than 250 14 by 17 inch films. As far as accuracy is concerned, we feel that the 4 by 5 inch stereoscopic photoroentgenograms are only slightly less accurate than 14 by 17 inch stereoscopic roentgenograms and more accurate than a single 14 by 17 standard roentgenogram. We do not place much faith in the 14 by 17 inch paper film. Obviously, the accuracy of any method can only be attested to by the number of errors made in a practical application. We have, at this writing, discovered only 3 cases of tuberculosis that we can consider as having been "missed" at our Induction Station. In addition, there is 1 case with an obvious abnormal heart as to size and configuration (probably rheumatic mitral disease) that was called normal. There was also a case of histoplasmosis of Darling involving the lungs that we had called negative. On reviewing this case it was noted that the lungs had an appearance not unlike that seen in cases of interstitial fibrosis. Aside from these 5 cases we know of no other errors that we have made out of these 102,247 inductees examined. There may be other errors in diagnosis that will be discovered later but we feel more than satisfied with the accuracy of this method.

Finally, there is an important public health and economic aspect to this entire subject. We may safely conclude that a large number of these inductees who were rejected because of pulmonary tuberculosis and other chest diseases were probably the "silent sick" of the community. Many were spreading tuberculosis among relatives and friends, unaware of the nature of their illness. There is considerable hope that these men have been isolated from the rest of the community, and that many chronically ill may be rehabilitated in the future. The saving to the Government in terms of dollars and cents in discovering these various chest diseases is inestimable. Spillman[6] has demonstrated that the average inductee taken into the Army with tuberculosis ultimately costs the government $10,000. It takes very little arithmetic to convince the unconverted as to the practicability and wisdom in obtaining routine chest roentgenograms on all inductees.

SUMMARY AND CONCLUSIONS

1. An analysis of roentgenographic chest examinations on 102,247 Southern Negro inductees at Fort Benning, Georgia, has been presented.

2. The rejectable cases have been divided into four large groups as follows:

   (a) Tuberculosis, with a subgroup of tuberculous lesions deferred for six months.
   (b) Other lung diseases.
   (c) A miscellaneous group—including diseases of the thoracic cage, mediastinum, pleura, diaphragm and dorsal spine.
   (d) Abnormalities of the heart and great vessels.

3. A tabular summary of each of the four groups has been presented and a brief discussion of each group has been given where necessary.

4. It has been shown that there is probably no significant difference as to the incidence of pulmonary tuberculosis in our group of Negro inductees in comparison with other large groups.

5. An astonishingly high percentage of inductees with roentgenographic evidence of pneumonia have presented themselves for examination.

6. The methods used in our chest examinations have been given.

7. The general value of the 4 by 5 inch stereoscopic roentgenograms made with the Army photoroentgen unit has been reaffirmed.

8. The importance of routine chest roentgenograms for all Army inductees has again been stressed.

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PSEUDOMYXOMA PERITONAEI

REPORT OF A CASE WITH UNUSUAL ROENTGEN FINDINGS

By CLAYTON G. WEIG, M.D., *Fellow in Roentgenology*, EDWARD C. KOENIG, M.D., *Director of Department of Roentgenology, and* GORDON J. CULVER, M.D., *Assistant Roentgenologist*
Buffalo General Hospital
BUFFALO, NEW YORK

THIS paper does not purport to be a comprehensive review of pseudomyxoma peritonaei, but rather the report of a case with certain roentgenographic findings which should be readily recognized whenever present. However, a few historical facts and salient features of the condition are worth mentioning. It was first recognized and described by Werth in 1884, and in 1901 Fraenkel observed the process in a male following the rupture of a mucocele of the appendix. Since that time at least 50 cases of appendiceal origin[1,7] and many more cases of ovarian origin have been reported. Rupture of a pseudomucinous cystadenoma of the ovary is by far the most common cause when one considers that these tumors comprise 75 per cent of all ovarian neoplasms,[2] and that the incidence of mucocele of the appendix based on the figures of Kelly, Castle, and Danreuther, is only 0.1 to 0.3 per cent.

Regardless of the primary source of the lesion the pathogenesis of pseudomyxoma peritonaei is essentially the same, although Chaffee and LeGrand[1] have made some attempt to differentiate the process arising from the appendix from that originating in the ovary. In both instances one premise must of necessity always exist: namely, the rupture of a sac or primary cyst containing mucinous or pseudomucinous material with the extrusion of the latter into the peritoneal cavity. This sac may be a pseudomucinous cystadenoma of the ovary, a mucocele of the appendix, or any blind pouch containing mucus-secreting epitheliai cells. Soon after rupture of the primary cyst, the exudate, which is of a tenacious, mucoid character varying in color from a golden yellow to a dark brown depending upon the hemorrhage, fatty tissue, cholesterol, and cellular detritus contained therein, becomes diffusely distributed over the entire abdomen. Both visceral and parietal surfaces of the peritoneum and also the mesentery become involved. Later on, generalized peritoneal thickening and cellular infiltrations occur with the formation of connective tissue producing firm adhesion bands. Simultaneously, there is proliferation of secondary tumors with the resultant production of multiple smaller cysts. Whether or not the mucoid material in itself is capable of giving rise to these secondary lesions is still an unsettled question, but some workers have strong experimental evidence in favor of the theory of cellular implantation.[4]

The presenting symptoms are usually those of a gradually enlarging abdomen, abdominal pain, or those of a partial bowel obstruction. Masson and Hamrick[5] state that the average duration of life after the onset of illness is 4.3 years, but report some cases still living eleven and twelve years after the first appearance of symptoms. Intestinal obstruction, pulmonary embolism and peritonitis following surgery, and intercurrent infection when the cysts perforate hollow viscera are listed as the most common causes of death. The following case illustrates many of the above mentioned facts, and in addition exhibits some characteristic roentgen findings.

CASE REPORT

H. M., female, aged twenty-seven, was admited to another hospital on October 22, 1930, complaining of a large mass in the left side of the abdomen, which she had noticed for the past three weeks. During the past six months the menses had been scanty and irregular, and the last period, about two weeks ago, was accompanied by almost unbearable pain in the

left lower quadrant. For two years prior to the present illness the patient had complained of generalized and indefinite pains in this area. Past history revealed an operation on the uterus in 1921, the nature of which surgery could not be determined. In the same year an appendectomy and salpingectomy were performed. Two years later the right cornu of the uterus was resected, and at this time the patient was observed to have bilateral polycystic ovaries. Additional surgery prior to the present hospitalization included a cholecystectomy in 1925, and a dilatation and curettage following a miscarriage in 1926.

Physical examination revealed a white female of the apparent stated age, not appearing acutely ill. There were surgical scars in the right upper and both lower quadrants. In the left lower quadrant there was a firm, very tender, grapefruit-sized mass. The day after admission the abdomen was opened under spinal anesthesia through a midline incision, and an orange-sized cyst of the left ovary was found. In part the operative report stated: "The cyst was walled off with sponges and a trocar and cannula inserted. About one quart of dark brown fluid escaped. The anterior portion of the cyst wall was excised and the remainder marsupialized. A rubber drain was inserted into the cavity." On the fourth postoperative day the drain was removed, and the patient was discharged three days later. The pathological report of the tissue removed merely stated "cyst wall."

The patient was admitted to this hospital for the first time on December 6, 1932, complaining of pain in the right costovertebral angle of five days' duration which radiated to the mid-epigastrium. There were no genitourinary symptoms, however. Physical signs were essentially negative except for some tenderness and spasm in both right upper and left lower quadrants. The final impression was one of possible adhesions and she was discharged eight days after admission.

In November, 1935, the patient was admitted to this hospital for the second time still complaining of pain in the right costovertebral angle. Physical examination showed tenderness to percussion over both costovertebral angles, more marked on the right, and abdominal tenderness along the course of both ureters. There was a hard, nodular, indefinite mass in the left lower quadrant which was tender to palpation. Cystoscopy disclosed a cystitis and trigonitis, but retrograde pyelograms were within average, normal limits and no stone shadows were demonstrable. A single flat roentgenogram of the abdomen showed a few small calcified areas opposite the transverse processes of the fourth and fifth lumbar vertebrae on the right and several rounded calcified densities along with a few phleboliths in the pelvic area. Unfortunately, this roentgenogram is not now available. On pelvic examination a diffuse tender enlargement was felt in the left fornix, and, when sigmoidoscopy was attempted, because of rectal complaints the instrument could not be passed higher than a distance of 6 inches. The final diagnosis was postoperative adhesions and the patient was discharged after fifteen days in the hospital.

On March 11, 1938, the patient was again hospitalized, this time in an institution other than the two mentioned previously. Her complaints were essentially the same as on previous admissions, but the possibility of a uterine cancer was entertained because of increased menstrual pain and menorrhagia. The following day a dilatation and curettage and amputation of the cervix were done. Concluding this a laparotomy was performed, the operative report of which was as follows: "The abdomen was opened through a midline incision. A hard nodule $\frac{3}{4} \times \frac{1}{2}$ inch was found under the fascia and removed for examination. There was a mass in the left pelvic area comprised of left ovary, tube, and broad ligament. This was studded with numerous nodules like the one found in the anterior abdominal wall, and they varied in size from that of the head of a pin to that of a plum. Several were removed for examination. Similar nodules were found in the liver and gallbladder areas as well as in the omentum. Many adhesions were present and the pelvic mass appeared fixed. The abdomen was closed without drainage."

The pathological report on the tissue removed at surgery stated: "Gross: Uterine scrapings and wedge of cervical tissue show no gross abnormalities. There are two nodules measuring 1 to 1.5 cm. in diameter, which show central fibrosis and calcification, with a rim of soft pearly tissue resembling a lymph node. Smaller irregular nodules are completely calcified. Microscopic sections of uterine scrapings and cervical tissue show some luteal and late follicular phase of endometrium; microscopic sections of the nodules (Fig. 1) show a dense hya-

linized connective tissue enclosing small and larger gland-like spaces. These were apparently lined by epithelium, and in rare areas a few epithelial cells, degenerated and calcified, can be found. The cells are flattened or rounded now, and were apparently cuboidal or columnar, and in a single row. The gland spaces are regular and without papillary processes. The pathological process as seen in the nodules removed is apparently well under control and not active. Impression: Calcified pseudomyxomatosis peritonaei and luteal phase of the endometrium."

In October, 1942, the patient began to have cramp-like pains, which occurred at regular intervals a few days apart, in the region of the umbilicus. The attacks were sufficiently severe to cause her to "double up" and were of several minutes' duration. Hot vaginal douches were the most effective means of relieving this pain. In the early part of March, 1943, the attacks suddenly began to occur at much shorter intervals, sometimes as often as every fifteen minutes, and the pain became intensified immediately preceding a bowel movement. At this time she also had episodes of nausea, emesis of clear fluid, and twenty to thirty light colored, watery stools a day. Because of the known history of the case the patient was hospitalized and observed for a possible impending bowel obstruction. Besides the many surgical scars on the abdomen, examination revealed an orange-sized bulging of the abdominal wall to the right of and below the umbilicus. The mass appeared soft and there was no sensation of intra-abdominal mass beneath it. Generalized and rebound tenderness was present over the entire abdomen but more marked in the left lower quadrant. Rectal examination disclosed several small nodules in the anterior rectal wall and a shelf-like stricture on the anterior wall about 2 inches above the anal opening. A flat roentgenogram of the abdomen (Fig. 2*A*) showed multiple areas of cystic calcification, measuring from 0.2 to 1.3 cm. in diameter, scattered throughout the abdomen, but for the most part, in the pelvic and subphrenic areas. The calcified densities were discrete, and in areas where several did not overlie each other, could be seen to be round and smooth. A lateral view (Fig. 2*B*) only tended to substantiate the disseminated character of the lesion. There were small collections of gas throughout large and small bowel, but inconclusive evidence was present to warrant a diagnosis of bowel obstruction. When placed on a bland diet, antispasmodics, and sedation the symptoms subsided and the patient was discharged five days after admission.

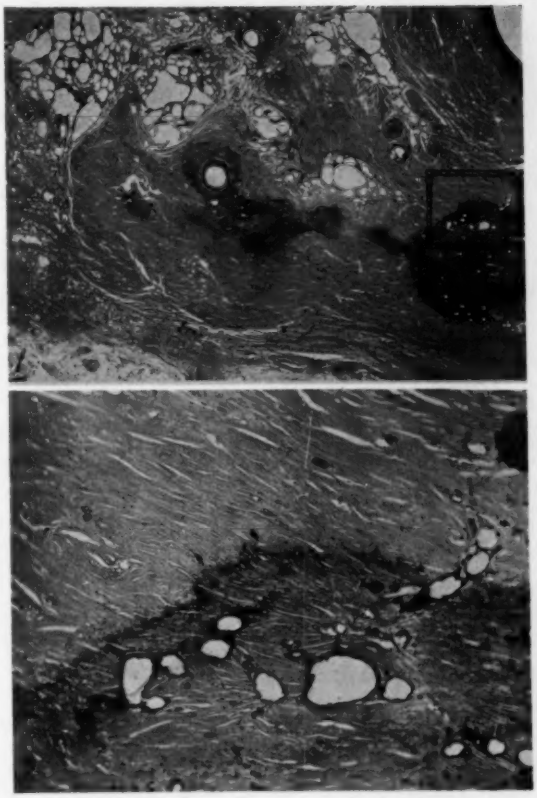

FIG. 1. *A*, a low power view showing the markedly fibrosed omentum with several small glands in cystic dilatation surrounded by firmly hyalinized and massively calcified connective tissue. In the upper field there are markedly dilated lymph vessels. Note the massive calcification of the entire wall of a cyst in the center. *B*, medium power view of the area marked on *A*. In some of the cysts a hazy, though mostly calcified, epithelial lining is recognizable, especially in the large cyst to the left, with some pseudomucinous secretion attached to the epithelial lining. Most of the walls, especially in the larger cysts, show complete calcification of the tunica propria.

DISCUSSION

The case presented exhibits the usual features of pseudomyxoma peritonaei and, in addition, an unusual if not extremely rare finding—calcification of the secondary peritoneal implants. In reviewing the re-

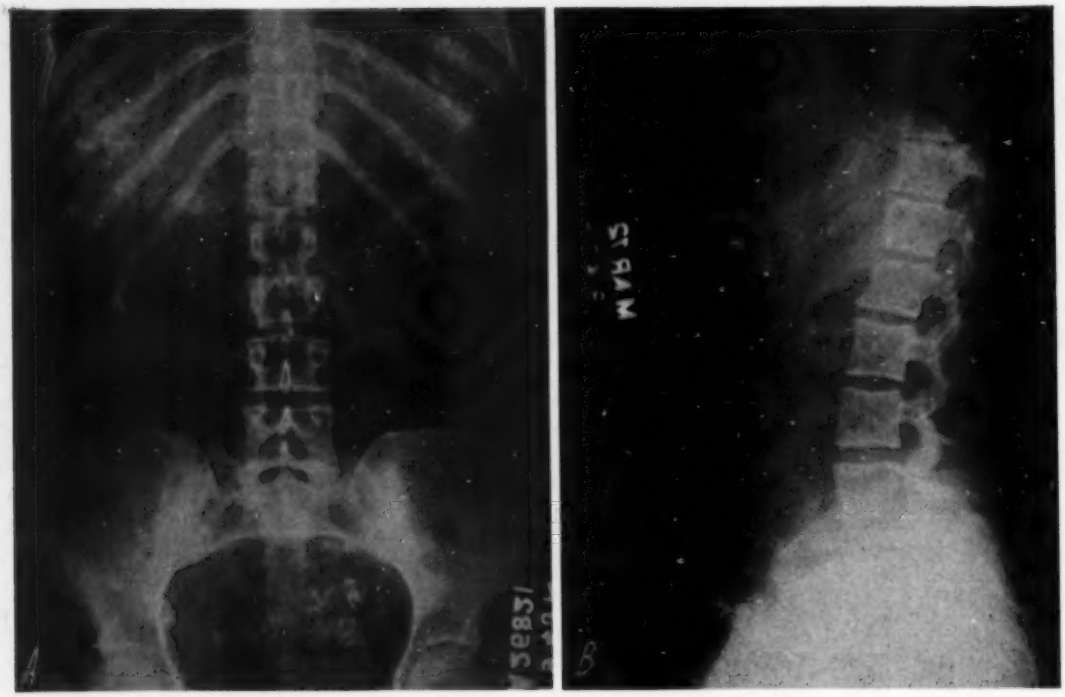

FIG. 2. *A*, anteroposterior view of the abdomen. *B*, lateral view of the abdomen.

cent literature we found only 2 cases, both reported by Pugh,[6] in which the roentgenographic findings were similar to those of the case presented. The first case, proved by laparotomy and showing the typical pathological changes of pseudomyxoma peritonaei, occurred in a male, aged thirty-two, and was probably of appendiceal origin. The second case, occurring in a female, aged fifty-three, was diagnosed as a probable peritoneal paraffinoma on the basis of a history of intra-abdominal instillation of some foreign substance to prevent adhesions and the pathologist's report of finding inflammable, meltable foreign substance in the cystic structure found at surgery. The author states that the latter case might well be one of pseudomyxoma peritonaei complicated by paraffinoma, as there was a history of previous surgery at which time one ovary and a cyst from the other were removed and "some ovarian material was scraped from the spine."

By the very nature of the lesion it is evident that the roentgen findings are limited to the abdomen. As viewed in the roentgenogram, the peritoneal implants show the typical appearance of any cystic calcification; the shadows are round, have smooth borders, and are of a greater density at the periphery than at the center. The lesions are multiple and discrete, although some may be in such proximity with each other as to give a lobulated appearance. They vary in size from a few to several millimeters in diameter and are widely distributed throughout the peritoneal cavity. Concerning their location, the greater number observed in the pelvic area can be readily explained by the fact that this region is the one most affected at the time of rupture of the primary cyst.

Having stated the general roentgen appearance of the lesions in this case, let us now consider other types of intra-abdominal calcifications which might be included in a differential diagnosis. Peritoneal paraffinoma with subsequent calcium degeneration might exhibit a similar roentgenographic picture. In these cases the correct

diagnosis may depend entirely upon the history. Calcified secondary echinococcus cysts would probably have a similar appearance in the roentgenogram, but here the presence of the much larger mother cyst in the liver should suffice to make the diagnosis. Calcified mesenteric nodes are apt to be fewer in number, show a greater and more uniform density, and exhibit more irregular borders. Phleboliths, biliary and urinary calculi, and localized calcification in uterine fibroids should readily be differentiated by their size, locality and difference in density. Enteroliths and fecal concretions containing sufficient calcium salts to cast a shadow are fewer in number but may cast similar shadows. Their location within the alimentary tract can be demonstrated by stereoscopic roentgenograms following contrast enemata. In a like manner, opaque medication and retained barium in diverticula may be also differentiated. We are not aware of calcification in endometrial transplants or abdominal metastases secondary to colloid carcinoma of the ovary.

In addition to the singular roentgenological aspects, the case presented exhibits a rational correlation between these findings and the clinical course of the disease. Although the condition was not accurately diagnosed until 1938, it will be remembered that the rupture of the ovarian cyst occurred in 1930, and that the first roentgen evidence of peritoneal affection was observed five years later. In the eight years following this observation the lesions have shown a marked increase in calcification. According to Ewing,[3] calcification is a striking feature of the epithelial elements of certain tumors, indicating a limited degree of growth capacity and a tendency toward spontaneous regression. The patient whose case is reported is still alive and well, now thirteen years after the onset of symptoms. Undoubtedly she will experience recurrent episodes of low grade bowel obstruction in the future, but the growth of the secondary cysts has in all probability ceased.

CONCLUSIONS

1. A brief résumé of the history and pathogenesis of pseudomyxoma peritonaei is presented.

2. A case with unusual roentgenographic findings is reported.

3. The roentgen findings, differential diagnosis, and clinical course of the disease are discussed.

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DIVERTICULUM OF THE STOMACH

CASE REPORT

By LUDWIG L. FRANK, M.D.
Staats Hospital
CHARLESTON, WEST VIRGINIA

DIVERTICULA of the stomach are interesting but infrequent findings, only 150 cases being reported so far in the literature.[4] Incidence is given by all writers on this subject as far below 0.5 per cent of all gastrointestinal examinations performed.[19] Only one author was found to have reported an incidence of 0.65 per cent of all his gastrointestinal examinations.[27] Regarding the order of frequency of diverticula of the alimentary tract, incidence of gastric diverticula is placed almost at the end of the list,[21] preceding in number only the exceedingly rare diverticula of the jejuno-ileum.

There is much want of clearness in classifying these abnormalities. The rigid differentiation between congenital and acquired gastric diverticula, the latter said to be caused either by pulsion or traction,[2,26] now seems to be abandoned in favor of a tripartition: congenital, acquired and false. The first two categories are called true diverticula because they contain all layers of the stomach wall, whereas the false diverticula show at least one layer missing.[9,21] A third classification differentiates the true diverticula, all of them probably congenital, from the false ones, all of the latter acquired, either by pulsion or, more frequently, by traction.[4] Martin[12] is of the opinion that all diverticula of the pulsion type are congenital, those of the traction type acquired.

We do not believe that these attempts to classify gastric diverticula rigidly along pathologico-anatomical lines can be accepted from a clinical point of view. For the clinician, it does not make much difference in his attitude toward the case whether or not all coats of the gastric wall are present. Furthermore, it seems to be doubtful whether all so-called false diverticula with one or more coats of the stomach wall missing are due to a break in the gastric wall resulting from disease, either inflammatory or ulcerative or neoplastic. Finally, it is impossible for the diagnostician to establish from the roentgen evidence a firm decision as to what pathologico-anatomical group his case belongs. There are only two points which matter to him: (1) that the diagnosis of a diverticulum on roentgen examination is correct; (2) whether and how many of the symptoms complained of can be referred to the diverticulum found roentgenologically.

It is certain that the definitely congenital diverticula are extremely rare, so rare that only the so-called pancreas diverticula of Nauwerck[15] once were believed to be congenital.[2] It should be noted that Rivers, Stevens and Kirklin,[21] referring to 14 proved cases of true diverticula of the stomach, did not find pancreatic tissue in any of their cases.

The most frequent localization of gastric diverticula is in the cardiac region.[4,19,20,21,29] Next in frequency are the diverticula in the pyloric region.[4,17,19,21,29] Gastric diverticula some distance from the pylorus are least frequently found.[19,21,29]

We had the opportunity some time ago to observe the following case:

Mrs. H. D. S. (No. 28342), aged seventy-one. Some digestive disturbance and chronic constipation since first pregnancy in 1902. Appetite has always been good. When she eats raw or coarse food, she complains of gas, feels some soreness in the pit of the stomach and much discomfort in the lower bowel. Otherwise no stomach or abdominal complaints. General condition good. Blood pressure 135/75. Roentgen examination revealed a large diverticulum at the lesser curvature near the cardia. The entrance of the diverticulum is wide and a gas-bubble is seen in the upper part of it (Fig. 1–3). Marked gastrocoloptosis and redundancy of the left

flexure were noted in addition. Without any special treatment and notwithstanding her advanced age, patient has been getting along perfectly well up to the present time.

It is not important to discuss the symptomatology of gastric diverticula at any great length. The clinical symptoms are always as inconclusive as they have been in the case under discussion and diagnosis has to be made in all instances by roentgen examination. Credit of the discovery of gastric diverticula as a pathologic entity has been given to Fournier in 1774;[19] the first report is said to have been made by Helmont in 1804.[3] These two statements are explicitly refuted as erroneous in the exhaustive study of Martin[12] who credits Thomas Baillie with the description of the first authentic case in 1793. G. E. Brown in 1916 is said to have been the first one to demonstrate a gastric diverticulum before operation.[12,19] Thereupon, the number of cases multiplied, by far the most of the reported cases being based on characteristic findings when routine roentgen examination was done for a gastrointestinal disorder of some kind. Many diverticula do not cause any symptoms[4] and are found incidentally or at autopsy. In other cases, ambiguous symptoms of different nature and varying degree are complained of, not a single one of which can be called pathognomonic. When roentgenological investigation is done, the finding of a gastric diverticulum comes to the examiner as a surprise in the overwhelming majority of cases, if not in all.

Fig. 1. Diverticulum at the lesser curvature of the stomach near the cardia. Roentgenogram taken after one swallow of barium.

Fig. 2. Stomach filled with one glass of barium; patient is in reclining posteroanterior position.

Åkerlund in 1923 deserves credit for having written the first classical monograph dealing with roentgen diagnosis of gastric diverticula.[14] Since then, the diagnostic technique has not essentially changed.[19,21,26] All authors agree that there is no standard technique for visualization of gastric diverticula; gradual filling of the stomach, the use of different positions and angles, and—not the least—"diverticulum consciousness" of the examiner are of the greatest importance in their detection. Confusion with diaphragmatic hernia or ulcer crater[12] can be avoided by skillful maneuvers during examination.

Gastroscopy may be of some diagnostic help and is mentioned as such in recent literature.[16,19,22,23,24,25,29] Schindler was able to detect three diverticular openings in 1,000 cases gastroscoped. Tracey[29] is doubtful about the value of this procedure in the diagnosis of gastric diverticula, and he explicitly warns against the possibility of perforating a diverticulum with a wide opening in the cardiac region which is a rather inaccessible area for the gastroscope. He recommends gastroscopy in such cases only "if a capable surgeon should be within call in case of such a catastrophe." I feel that the danger of perforation in the presence of a diverticulum should not be overrated; however, the detection of a diverticular opening with the gastroscope is extremely difficult as everyone knows who does gastroscopy, and, besides, meticulous roentgen examination of the stomach is such an excellent means of diagnosing gastric diverticula that gastroscopy is not necessary for that purpose.

Fig. 3. Residue in diverticulum thirteen hours after barium meal; patient is upright in postero-anterior position.

The possibility of certain clinical complications has been mentioned in the literature: severe hemorrhage,[28] carcinomatous or sarcomatous degeneration in the walls of the diverticular sac,[6,13,14] and myomata.[7,8,11,18] All these complications are so extremely rare that they have none but academic interest.

Regarding treatment, a very different attitude is recommended by the different authors. Most of them agree that medical management is sufficient.[4,20,29] Some writers recommend the use of postural drainage in diverticula near the cardia.[5,20,21,29] Others advise surgery but only in diverticula of the distal two-thirds and if clinical symptoms or evidence of traction are present.[3,21] Whereas surgery in gastric diverticula near the cardia was denoted in 1926 as "an impracticable and usually impossible procedure,"[10] it is recommended quite recently in carefully selected cases under certain well defined indications.[29] Another author repudiates medical management of gastric diverticula as unsatisfactory and advises surgery in all cases without exception if diagnosis is certain.[19] There are certainly very few who would be inclined to follow such a radical advice in a condition which is usually harmless and nothing more than a roentgenological curiosity in the overwhelming majority of instances.

SUMMARY

A case of asymptomatic gastric diverticulum near the cardia in a woman, aged seventy-one, is presented and certain points of this rare condition are briefly discussed: classification, localization, symptomatology, diagnosis, complications and treatment.

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THE VALUE OF VENOGRAPHY IN VARICOSE VEINS
WITH REPORT OF THREE CASES

By CAPTAIN ALLISON E. IMLER
Medical Corps, Army of the United States
LIEUTENANT COLONEL MEREDITH G. BEAVER
Medical Corps, Army of the United States
and
LIEUTENANT COLONEL WILLIAM C. SHEEHAN
Medical Corps, Army of the United States

VENOGRAPHY is receiving more and more recognition as an aid in the diagnosis and treatment of vascular diseases of the lower extremities. Until recently most of the investigators have concerned themselves with studies of thrombophlebitis and the associated problem of pulmonary embolism.[5,17,22,23] Its use in the study of arteriovenous fistula[21] and venospasm[4,12] has widened its field of application. It is the purpose of this paper to show the value of venographic studies in selected cases of varicose veins.

Varicose veins are the most common disorder of the venous circulation of the lower extremity. It has been estimated that about 10 per cent of young healthy adults suffer from superficial varicosities.[3] Ligation, excision or injection can be expected to produce results in most cases where such treatment is indicated. The applicability of any one or a combination of these methods will vary with the individual case. The obliteration of the superficial channels is carried out with the supposition that the deep veins are patent and will adequately handle all the venous return.

Barrow[2] has made a comprehensive survey of the physiology associated with varicose veins. We are in agreement with him in that practically all cases of asymptomatic superficial varicosities show normal deep and communicating veins while incompetency of the deep and/or communicating veins is usually present in patients with severe symptoms. It has been pointed out that the severe symptoms and disabling complications associated with varicose veins are due to capillary hypertension and that a permanent cure can only be expected when the physiologic abnormalities have been corrected or compensated.[2] The frequency and importance of incompetent communicating veins in lower extremity varicosities is still an unsettled question.[2,7,9,10,14] Barrow reports that 86 per cent of the patients with superficial varicosities and incompetent communicating veins have a history of varicose ulcerations and that about 5 per cent of the patients with edema show obstruction to the deep circulation as demonstrated by the Perthes test.[20]

A careful physical examination with application of the Perthes and bandage[9] tests to determine the patency or occlusion of the deep veins and the Trendelenburg[18] and comparative tourniquet[10] tests to determine the competence or incompetence of the long saphenous and communicating veins will provide adequate information for a plan of successful treatment in a great percentage of cases.

The correct treatment of this condition necessitates a consideration of unfavorable postoperative sequelae and recurrence of varices following treatment. Operative and postoperative difficulties and hazards have been described by others[1,6,19] and will not be included in this paper. The recurrence of varices fall into two distinct groups: first, recurrence due to errors in technique or failure to observe certain precautions; second, in instances where the varicosities are associated with deep venous obstruction or marked stasis of the deep circulation.

Failures of high saphenous ligation, with

or without a retrograde injection of a sclerosing agent, are usually due to a lack of knowledge of the normal variations at the fossa ovalis.[6,9,16] Cases which Glasser has operated upon again show a patent medial or lateral superficial femoral vein. He reports no recurrences due to failure of ligation of the higher tributaries.

In instances of deep venous obstruction or marked stasis of the deep circulation, the superficial varicosities are compensatory and their obliteration will be followed by recurrence. This small but important group of cases should be identified by venographic studies and unnecessary or improper operative interference prevented. Clinically, all such patients will have severe symptoms of fatigue, pain on walking or standing and edema. The Perthes test and bandage test may show obstruction to the deep venous return. However, two most important facts must not be overlooked. First, there may be an almost complete stasis of the deep veins with compensatory varicosities of the superficial circulation. In such cases the patency tests will indicate an adequate circulation. Second, patency tests for the deep circulation may be misleading in that group of cases where the obstruction exists at or above the middle of the thigh.

A 35 per cent solution of diodrast is the most commonly used contrast medium. The possibility of serious sequelae following the use of this drug[8,13,15] necessitates a careful interrogation of each patient for a history of allergic manifestations and the application of a sensitivity test. Three instances of thrombosis of the deep veins of the leg have occurred following venography with 50 per cent diodrast. One of these was reported by Homans[8] and 2 additional cases were mentioned in an article by Scupham, de Takats, Van Dellen and Marcus.[15]

The following case reports are presented to illustrate the importance of venographic studies in selected cases of superficial varicosities.

REPORT OF CASES

Case 1 (Fig. 1 and 2). A white male, aged forty-two, was admitted to an Army general hospital complaining of severe varicosities of the left leg with marked weakness and slight swelling of that extremity. The patient gave a history of a severe contusion to the lateral aspect of the left thigh in 1918 but except for this the history was entirely negative until 1922. In the latter year the patient noticed weakness of the left leg, pain on walking or standing and varicose veins of the left leg and thigh. His symptoms became progressively worse and a roentgen examination in 1930 was negative except for myositis ossificans at the site of the

Fig. 1. Case 1. Marked dilatation and stasis of the posterior tibial veins with numerous varicosities of the long saphenous vein.

FIG. 2. Case 1. Opaque medium pooled in tibial veins even though the leg was elevated between exposures of Figures 1 and 2.

previous injury. Since entering active duty on November 6, 1942, the symptoms have increased in severity and on several occasions weakness and dizziness have caused him to lose his balance and fall to the ground. Physical examination revealed a blood pressure of 104/70 and extensive varicosities of the long and short saphenous veins. The Perthes test indicated a patent deep circulation. The Trendelenburg and comparative tourniquet tests revealed incompetence of the long saphenous and communicating veins. The symptoms were sufficiently severe to warrant venographic studies, which were done on July 12, 1943.

Comment. The venogram of the left lower extremity revealed marked stasis and dilatation of the tibial veins (Fig. 1). One segment of the posterior tibial vein measured 18 mm. in diameter. The proximal portions of the tibial veins were not well outlined due to the pooling of the opaque medium in the distal portions of the veins. Several incompetent communicating veins permitted visualization of the long saphenous vein and demonstrated its varicosities. The contrast medium passed from the long saphenous vein into the popliteal vein via the short saphenous vein. The long saphenous vein was not visualized above the level of the knee. The superficial femoral vein was slightly dilated. Serial roentgenograms showed emptying of the superficial system but the diodrast remained pooled in the distal portions of the tibial veins even though the leg was elevated to permit changing the cassette for the second exposure (Fig. 2). The conclusion reached was that the dilatation and stasis of the deep veins of the left leg were probably responsible for the development of the superficial varicosities and that obliteration of the varices was contraindicated. The symptoms of orthostatic collapse exhibited by this patient were considered to be secondary to the pooling of the blood in the left lower extremity. It was felt that operation would produce an aggravation of symptoms, probably permanent, in addition to provoking a recurrence of the varicosities. Local injections of sclerosing agents are definitely contraindicated because of the great possibility of producing a thrombosis in the tibial veins. If venous stasis is a prominent feature in the development of phlebothrombosis[11,24] then this patient is an excellent candidate for such an occurrence and any findings indicative of the onset of such a condition should be immediately followed by ligation of the femoral vein.

Case II (Fig. 3 and 4). A white male, aged thirty, was admitted to an Army general hospital for study and surgical treatment of a large varicosity of the right thigh, present since childhood. This patient gave a negative history up to four years ago since which time he has had a moderate but persistent dull ache in the right thigh, aggravated by excessive walking or running. There has been no demonstrable edema of the ankle or leg at any time. The patient has had no operations and there has been no history of trauma. Physical examination revealed a hemispherical, protruding varicosity at the junction of the proximal and middle thirds of the anteromedial aspect of the right thigh. This varicosity measured 2 cm. in diameter and was apparently a part of the long saphenous vein which was palpable along its entire length. Extending upward from the varicosity there was a large, superficial vein which coursed medially across the abdomen at the level of the symphysis pubis and was then directed caudally to enter the deeper tissues of the left thigh just below the inguinal ligament. Patency tests indicated an adequate deep circulation and the Trendelenburg test indicated an incompetent communicating vein at the site of the varicosity. Venograms were made on April 26, 1943.

Fig. 3. Case II. There is complete atresia of the right external iliac vein. The anomalous long saphenous vein permits the venous return from the right lower extremity to pass through the left external iliac vein.

Fig. 4. Case II. Compression of the anomalous saphenous vein forces some of the opaque medium through the right superficial circumflex iliac vein.

Comment. The venograms did not outline the superficial femoral vein beyond the level of the lesser trochanter of the right femur. The long saphenous vein was well outlined up to the varicosity where there were several large communicating veins between the superficial and deep venous systems. The long saphenous vein, taking an anomalous course, was directed medially to

Fig. 5. Case III. Complete block of the left superficial femoral vein is seen near the top of the roentgenogram.

pass superficially over the abdomen just above the symphysis pubis. All of the opaque medium from the right lower extremity was carried through the latter channel to empty directly into the left femoral vein and then passed through the left external iliac vein. A small amount of opaque medium was seen in an irregular and completely obstructed right external iliac vein. Another venogram was made with the diodrast injected into the long saphenous vein at about the mid-thigh. During the latter injection the anomalous long saphenous vein was compressed as it passed over the abdomen and this caused some of the opaque medium to pass through the right superficial iliac circumflex vein but the right external iliac vein was not visualized. Thus, for the second time, the patency of the right external iliac vein could not be demonstrated. The completely negative and long-standing history led to the conclusion that all the findings were on the basis of congenital anomaly. The diagnosis was congenital atresia, right external iliac vein, with an anomalous long saphenous vein carrying most of the venous return from the right lower extremity across the abdomen to pass through the left external iliac vein. On the basis of the venographic studies it was felt that operative interfer-

Fig. 6. Case III. The long saphenous vein is the only venous channel visualized in the upper two-thirds of the left thigh.

ence would produce a venous stasis and result in an aggravation of symptoms that in all probability would be permanent.

Case III (Fig. 5 and 6). A white male, aged forty-six, was admitted to an Army general hospital because of slight varicosities of both legs and edema of the left ankle. This patient gave a history of an appendectomy in November, 1933, and following the operation he developed a severe thrombophlebitis in the deep veins of the left thigh. The postoperative convalescence was further complicated by pulmonary embolism on three separate occasions. Bilateral superficial varicosities soon developed and have persisted. The patient has had pain and cramping in both legs on walking or running. Physical examination revealed moderate superficial varicosities in both lower extremities with slight pitting edema of the left ankle and leg. The Perthes test indicated a patent deep venous circulation in both lower extremities. The Trendelenburg test indicated a bilateral incompetence of the long saphenous veins and incompetence of the communicating veins on the left. Bilateral venograms were made on January 2, 1943.

Comment. The venogram of the right lower extremity showed a normal deep venous circulation and several small varicosities of the long saphenous vein below the knee. The venogram of the left lower extremity revealed a few varicosities of the long saphenous vein. The deep venous system was entirely normal up to the junction of the middle and lower thirds of the thigh at which point the patency of the superficial femoral vein was abruptly terminated. There were numerous anastomoses between the superficial and deep venous channels in the lower half of the thigh. The correlation of the history and the roentgen findings resulted in a diagnosis of thrombophlebitis, superficial femoral vein, left, healed, producing a complete obstruction of this vein. In the upper two-thirds of the left thigh, the long saphenous vein was the only venous channel visualized and the conclusion reached was that this patient's symptoms were on the basis of venous stasis and that ligation and injection of the long saphenous vein for control of the varicosities was contraindicated. Obviously, such operative interference would have produced an aggravation of symptoms, probably permanent in character.

The technique of venography is the same as that reported in a previous paper.[12] No untoward reactions have occurred.

SUMMARY AND CONCLUSIONS

Superficial varicosities are compensatory in obstruction or marked stasis of the deep veins. The positive evidence of venographic studies will defer surgical interference that might result in a permanent aggravation of symptoms in addition to a recurrence of the varicosities.

Considerable deep venous pathology may exist even though the patency tests indicate an adequate circulation.

The indications for venographic studies in cases of superficial varicosities are: (1) patients with a history of thrombosis or thrombophlebitis; (2) patients having severe symptoms of fatigue, pain on walking or standing, edema, or symptoms of orthostatic collapse, and (3) those few instances where anomaly of major channels is suspected.

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RENAL DYSTOPIA DUE TO INTRA-ABDOMINAL MASSES

WITH A REVIEW OF THE LITERATURE AND REPORT OF FIVE CASES

By H. R. FISHBACK, JR., M.D.
From the Department of Roentgenology, Harper Hospital
DETROIT, MICHIGAN

DISPLACEMENT of the kidney by intrarenal tumors or by extrarenal retroperitoneal masses is well known. Similar dislocation of the kidney by intra-abdominal masses is apparently not so well known. It is the purpose of this paper to emphasize the latter possibility and to call attention to intra-abdominal masses in a discussion of the differential diagnosis of renal dystopia.

REVIEW OF THE LITERATURE

In 1895, Dreyzehner[4] described a case of a pancreatic cyst which caused a rotation of one kidney; this was proved at operation. The author also reported that he had found 59 cases of pancreatic cysts in the previous literature; none of these, as far as could be ascertained, described any kidney displacement.

Bachrach and Hitzenberger[1] in 1930 presented the first case reported in the literature of kidney displacement caused by an enlarged spleen. They also described a case of hepatomegaly which caused similar displacement and reported other cases of splenomegaly, hepatomegaly, and an enlarged gallbladder which caused distortion of the kidney calices. It was their conclusion that extrarenal tumors (of the liver, spleen and gallbladder) could so affect the kidney that by pyelographic examination it would be impossible to differentiate them from intrarenal tumors. Haslinger[11] described a case of splenomegaly (etiology: Hodgkin's disease) where a pyelogram showed a downward displacement of the kidney; this was verified at operation. Another case, empyema of the gallbladder, also showed the right kidney to be pushed downwards by the tumor mass. Ecarius[5] reported a case of an enlarged spleen (due to "angioendothelioma sarcomatosum et cavernosum") where the left kidney was displaced far to the right, across the midline. This was the first case to be reported which showed such marked displacement of the kidney by splenomegaly.

Haenisch[10] in 1931 presented 2 cases of renal displacement, one by an enlarged liver (of luetic etiology) and the other by an enormous gallbladder; in both of these cases, displacement was proved by operation.

Guyot, Villar and Traissac[9] in 1932 stressed the importance of using pyelography when dealing with abdominal tumors.

Friedl[6] in 1933 described a case of leukemia; here a greatly enlarged spleen caused displacement of the left kidney forward, downward and toward the right, past the midline.

Rapant and Bedrna[17] presented 2 cases of an enlarged spleen (one a splenic cyst and the other myelogenous leukemia) where there was medial and downward displacement of the left kidney. The authors stressed that such displacement, however, is not pathognomonic of splenic tumors because retroperitoneal masses will cause the same type of displacement.

In 1934, Mertz and Hamer,[15] reporting on the use of the lateral pyelogram in urologic diagnosis, said that with intraperitoneal tumors there seemed to be less tendency to vertical displacement or vertical rotation of the kidney. They presented a mixed series of cases one of which was an angioma of the liver; here pyelographic findings showed marked horizontal rotation of the right kidney. The other case was a sarcoma of the head of the pancreas which caused marked horizontal and moderate vertical rotation of the right kidney with definite anterior

displacement of the ureter and lower pole of the kidney. Gloor[7] presented the first cases reported in the literature of a splenic tumor causing kidney displacement. He described two types of such displacement: (1) a vertical dislocation caused by pressure of an enlarged spleen on a floating kidney, and (2) horizontal displacement toward the midline caused by formation of intimate adhesions between the capsules of the kidney and spleen.

Bigliardi[2] in 1935 discussed the use of intravenous urography in the differential diagnosis of abdominal tumors and concluded that such examinations should not be exclusively reserved for urologists but rather should be applied also to the localization of abdominal tumors.

In 1936, Shambaugh[19] at the Peter Bent Brigham Hospital, Boston, reviewed a series of 24 cases where the urologist was called in consultation to assist in determining the location of abdominal masses. Of these cases only one showed kidney displacement due to an enlarged spleen. In conclusion, the author stated his opinion that enlargement of the spleen, even when massive, almost never disturbed the position of the left kidney. He also stressed the point that a congenital malformation of the kidney may be confused with a true displacement.

Hyman and Wilhelm[12] in 1938, reporting on the differential diagnosis of renal and suprarenal tumors, presented a case of liver cirrhosis with marked splenic enlargement where a retrograde pyelogram revealed downward and mesial displacement of the left kidney. They concluded that tumors arising in the suprarenal region, when they attain a large size, dislocate the kidney but do not usually distort or obliterate the upper calices.

Wyler[22] described a number of extrarenal tumors among which was a case of splenomegaly (etiology: polycythemia); at operation this enlarged spleen was shown to have displaced the kidney. He also presented a case of hepatomegaly in which the liver did not displace the kidney and he said that in his experience he had never seen kidney displacement associated with any gallbladder condition.

In 1939 at the Mayo Clinic, after reviewing a large series of urograms made in cases of intra-abdominal tumors, Schulte and Emmett[18] concluded that intra-abdominal tumors will not regularly displace the kidney or ureter but that a lesion of any abdominal organ *may* displace the kidney. Among their cases, they presented (1) a case of a cyst attached to the left lobe of the liver which resulted in downward displacement and rotation of the left kidney, proved by excretory urogram; (2) a case of hydrops of the gallbladder which produced a downward displacement of the right kidney, proved by retrograde pyelography, and (3) a large spleen which caused downward displacement and rotation of the left kidney, proved by retrograde pyelography. Weyrauch,[21] in discussing the use of the lateral pyelogram in a determination of the significance of renal torsion (in the diagnosis of retroperitoneal tumors) presented 3 cases of intraperitoneal masses, one of splenomegaly with displacement of the left kidney slightly medially, another of an epidermoid cyst of the spleen with displacement of the left kidney markedly downward and medially, and one of an enlarged liver (metastatic carcinoma) with displacement of the kidney also downward and medially. He concluded that splenomegaly and hepatomegaly may produce any type of renal torsion and result in a downward and medial displacement of the kidney. He also stated that in order to produce renal torsion, an intraperitoneal mass must be of considerable size and solidity and must project into the renal fossa.

Kretschmer[13] reported a case of subphrenic abscess with displacement of kidney and liver downward and another case of a pancreatic cyst which caused downward displacement of the right kidney with also displacement of the right ureter.

Kummer[14] also described a case of a cyst of the pancreas, proved at operation, and another case of splenic enlargement (etiol-

ogy: hemolytic icterus) both of which caused kidney displacement.

In 1940 Muschat and Edeiken[16] made a study of renal displacement and presented cases of splenomegaly, splenic infarction, pancreatic cyst and subdiaphragmatic cyst which caused displacement of the kidney. From their studies they concluded that the liver would *not* cause renal dystopia, and that in most cases of kidney displacement caused by intra-abdominal masses one hardly ever finds abnormal microscopic findings in the urine. Weiss[20] presented 5 cases in which an enlarged spleen caused either displacement of the kidney or compression deformity of the kidney calices. He commented that the latter effect of splenomegaly is more common than has

TABLE I

		Splenomegaly	Hepatomegaly	Splenomegaly and Hepatomegaly	Pancreatic Disease	Miscellaneous (Mesenteric tumor, Hydrops of gallbladder, Cyst of gallbladder, Mass of unknown etiology)
Kidney displacement proved by	a. pyelography and operation	1	1		1	
	b. flat plate	1		1		
No displacement shown by	a. pyelography	0				
	b. operation	5	6	3	3	3
	c. flat plate	2	2	1	3	
No. of cases		9	9	5	7	3
Cases with *no* pyelography, no operation and no flat plate		10	1	12		1
No. of cases		10	1	12		1
Total Cases		19	10	17	7	4

presented cases of hepatomegaly, carcinoma of the liver and hydatid cyst to prove this.

Guardabassi[8] described a number of cases among which was a splenic cyst (echinococcus), a pancreatic tumor, and an enlarged liver (carcinoma), all of which caused kidney displacement.

In 1941 Cremer[3] presented, among a group of cases, 2 of renal distortion caused by splenomegaly. He concluded that displacement of the kidney or ureters or distortion of the calices cannot by themselves help differentiate between retroperitoneal and intra-abdominal tumors. He stressed the advisability of roentgen examination of the gastrointestinal tract as well as retrograde pyelography. He also pointed out been believed, but that many more cases will have to be studied in order to establish just how often such distortion occurs.

REPORT OF CASES

At Harper Hospital in the last four and one-half years there have been 57 cases of splenomegaly, hepatomegaly, pancreatic tumors or miscellaneous intra-abdominal masses which might have caused displacement of the kidney. Of the total only 34 had either pyelography, a flat plate of the abdomen or an operation done to see if there was such displacement. Of this latter number, 5 cases, or 14 per cent, showed renal dystopia (Table 1).

CASE 1. A forty-three year old colored, married female whose only complaint was "pain in

Fig. 1. Case 1. A retrograde pyelogram showing marked displacement of the left kidney across the midline to the right.

the left side" of three weeks' duration. Physical examination revealed the presence of a large hard, non-tender mass about 6 by 5 inches in size in the left upper quadrant. The essential laboratory findings were: hemoglobin, 42 per cent; erythrocytes, 2.78 million; leukocytes, 5,300 and Kahn 3+ (repeat Kahn, "doubtful"). A gastrointestinal series showed no roentgen evidence of an intrinsic upper gastrointestinal lesion. There was marked displacement of the stomach and upper small intestine on the right by the large left tumor mass. Retrograde pyelography showed the left kidney to be pushed markedly to the right toward the midline (Fig. 1 and 2). On the basis of these findings the clinical impression by the urologists was a retroperitoneal sarcoma, probably inoperable; the internists believed the mass to be an enlarged spleen. A laparotomy revealed the presence of a very large spleen; this was attached by many adhesions to the left kidney capsule and after removing the spleen the kidney was restored to its normal position automatically. Pathological examination of the spleen showed "an old fibrosis and congestion with organized areas of necrosis due to previous thrombosis of the splenic vein." The patient made an uneventful recovery following operation.

Case II. A female, white, married, aged fifty-one, whose chief complaint was "severe pain in the left side" of one week's duration. The pain was so severe that it doubled her up and she could not get her breath. Physical examination revealed a visible mass about the size of a grapefruit in the left upper quadrant; this was tender to palpation and seemed to be more anterior than posterior. Essential laboratory findings: hemoglobin, 90 per cent; erythrocytes, 4.90 million; leukocytes, 7,400, Kahn reaction negative. A retrograde pyelogram showed some lateral displacement of the upper portion of the left kidney.

Clinical impression was a definite retroperitoneal mass. Therefore, an exploratory operation of the left kidney was done; the kidney appeared normal and there were a few hard glands

Fig. 2. Case 1. Roentgenogram from a gastrointestinal series showing the marked displacement of the stomach and upper small intestine on the right by the large left tumor mass.

lying between the kidney and the vertebral column. The large mass previously reported was definitely in the peritoneal cavity. Following this operation the patient developed aspiration pneumonia and ran a rather stormy course for about a week. Two weeks after the pneumonia cleared up an exploratory laparotomy was done; the stomach was markedly displaced to the right side. Further examination revealed a large tumor mass which extended well up into the left dome of the diaphragm, displacing the liver and stomach to the right. The tumor extended down into the right side well below the liver level; it was firm, smooth in outline and appeared to rise from the pancreatic area. The spleen was displaced but was of normal size and shape. Final diagnosis was a pancreatic tumor (Fig. 3).

Case III. A female, white, married, aged fifty-eight, whose chief complaint was "a mass with pain in the left upper part of the abdomen" associated with progressive weakness and ease of fatigue. Physical examination showed palpable cervical and axillary glands. The spleen was enlarged, a hand's breadth below the umbilicus. Essential laboratory findings: erythrocytes, 3.20 million; leukocytes, 91,000, lymphocytes, 94 per cent; Kahn reaction negative. Roentgenographic examination of the urinary tract showed displacement of the left kidney downward. Final diagnosis was subacute lymphatic leukemia (Fig. 4).

Fig. 3. Case II. A retrograde pyelogram showing lateral displacement of the upper portion of the left kidney.

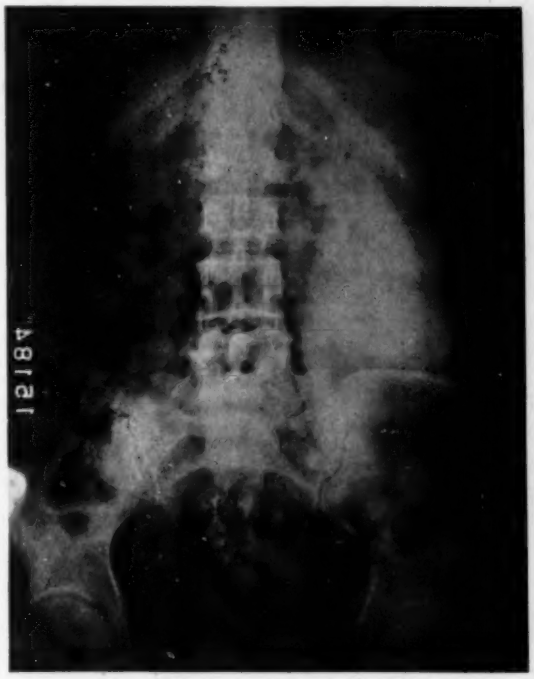

Fig. 4. Case III. A flat roentgenogram of the abdomen showing the left kidney displaced downward.

Case IV. A white, single Italian male, aged thirty-six, whose chief complaint was "swelling of the abdomen" of two weeks' duration. This was associated with some swelling of his ankles but he had no dyspnea, orthopnea or precordial pain. The only item of interest in his past history was an acute attack of "rheumatism" at the age of eight. Physical examination revealed a markedly distended abdomen with a palpable fluid wave and shifting dullness. The liver edge was down about four to five fingerbreadths but the spleen was not palpable because of the marked distention. Essential laboratory findings were: hemoglobin, 82 per cent; erythrocytes, 4.50 million; leukocytes, 5,350; icteric index of 13, prothrombin time of 60 per cent and Kahn reaction negative. A flat plate of the abdomen showed enlargement of the spleen with displacement of the left kidney toward the midline. Final diagnosis was Banti's syndrome (Fig. 5).

Fig. 5. Case iv. A flat roentgenogram of the abdomen showing displacement of the left kidney toward the midline.

Case v. A white, married male, aged fifty-three, whose chief complaints were "weight loss" and gaseous eructations of three months' duration and epigastric pain of six weeks' duration prior to admission. The patient said he had malaria in 1906 and typhoid fever in 1907, both without apparent complications. Physical examination revealed a fairly elderly male of dark complexion, appearing chronically ill but who was alert. The liver extended about six to seven fingerbreadths below the right costal border and the edge was sharp, hard and nonnodular. Spleen was palpable. Essential laboratory findings were: hemoglobin, 71 per cent; erythrocytes, 3.80 million, and leukocytes 6,900.

A flat plate of the abdomen gave roentgen evidence of a large mass which was "apparently an enormously enlarged liver." A laparoscopic examination was done which revealed "many strands and planes of rather well organized delicate adhesions partitioning the pneumoperitoneal space into many small pockets." Three months later an exploratory laparotomy was done and the liver was found to be "entirely involved with carcinoma which left no portion of the liver normal." The spleen was also enlarged and the right kidney was displaced anteriorly and medialward. Final diagnosis was primary carcinoma of the liver; this was later also proved at autopsy (Fig. 6).

Fig. 6. Case v. An intravenous pyelogram showing the left kidney rotated on its axis.

COMMENT

A survey of the literature regarding renal dystopia seems to indicate that while displacement of the kidney by intra-abdominal masses is not common yet it can and does occur.

Although in the literature the individual authors express such varying opinions as splenic enlargement almost never disturbs the position of the left kidney (Shambaugh[19]), or kidney displacement is never seen associated with any gallbladder condition (Wyler[22]), or the liver does not cause renal dystopia (Muschat and Edeiken[16]), their colleagues have reported cases which disprove these statements.

The best explanation of the mechanical

displacement of the kidney by the spleen is that given by Gloor[7] who described such dystopia as caused by (1) pressure of the spleen on a floating kidney, thus dislocating the latter downward, or (2) adhesions between the capsules of the kidney and spleen causing horizontal displacement of the kidney toward the midline. It is noteworthy that in the first case I presented the urologists believed the renal dystopia was definitely due to a retroperitoneal mass because a good explanation for such marked displacement by the spleen could not be found. If the surgeons had not insisted on an exploratory laparotomy, nothing would have been done for the patient and she probably would have continued on a downward course.

The possibility of an intra-abdominal mass is important to include in the differential diagnosis of renal dystopia in order that a more complete case evaluation can be determined. In the second case presented, because of the renal displacement as shown by retrograde pyelography, the clinical impression was a retroperitoneal mass; this was not borne out by operation which revealed instead an intra-abdominal mass arising from the pancreas.

Table II

	Physical Examination	Type of Roentgen Examination	Roentgen Findings	Diagnosis
Case I Mrs. E. J. (263456)	Mass in left upper quadrant extending from left costal region to midline and well down toward pelvis	Retrograde pyelogram	Displacement of the left kidney to the right	Splenic vein thrombus (etiology, syphilis) causing splenic infarction and splenomegaly
Case II Mrs. E. Y. (236538)	Mass in left upper quadrant, tender, size of a grapefruit	Retrograde pyelogram	Lateral displacement of the upper portion of the left kidney	Pancreatic tumor
Case III Mrs. C. S. (217193)	Large spleen, hand's breadth below the umbilicus, to level of crest of ilium	Flat plate of the abdomen	Left kidney displaced downward	Subacute lymphatic leukemia
Case IV Mr. R. P. (225282)	Liver down about 4 to 5 finger breadths. Spleen not palpable due to marked distention	Flat plate of the abdomen	Left kidney displaced toward the midline	Banti's syndrome
Case V Mr. C. F. (220823)	Liver down about 6 to 7 finger breadths; edge sharp, hard, non-nodular. Spleen palpable	Intravenous pyelogram	Rotation of the left kidney on its axis	Primary carcinoma of the liver

CONCLUSIONS

Concerning renal displacement by intra-abdominal masses:

(1) A review of the literature is given.

(2) Five new cases are presented.

(3) The importance of such masses in the differential diagnosis of renal dystopia is stressed.

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THE EFFECTS OF REPEATED IRRADIATION OF THE GASTRIC REGION WITH SMALL DOSES OF ROENTGEN RAYS UPON THE STOMACH AND BLOOD OF DOGS

By W. C. HUEPER *and* J. DE CARVAJAL-FORERO
Warner Institute for Therapeutic Research
NEW YORK, NEW YORK

IT IS known from previous investigations (Desjardins; Palmer and Templeton; Miescher; Ivy, Orndoff, Jacoby and Whitlow; Case and Boldyreff) that the roentgen irradiation of the stomach of experimental animals, including dogs, results in a depression or suppression of the gastric secretion, characterized by a lowering of the free and total acid, a reduced volume of secretion, and a decreased pepsin content of the gastric juice. No studies have been made so far as to the action of such a treatment upon the erythropoietic activity of the bone marrow and upon the blood through a possible effect upon the production of the so-called "intrinsic factor" of Castle.

The present communication relates the observations made on the blood and internal organs of dogs which were irradiated over the gastric region with small doses of roentgen rays over prolonged periods of time.

EXPERIMENTAL PROCEDURE

Seven mongrel dogs weighing from 5.2 to 9.6 kg. at the start of the experiment were subjected to a series of roentgen irradiations over the gastroduodenal region. The rest of the abdomen was protected by lead sheeting. The treatments were given on five days of the week using each day a different filter in the order given below and reversing the portal weekly (anterior and posterior portals) so as to insure a uniform exposure of the entire viscus. The filters used were 1 mm., 2 mm., 3 mm. Al, 0.25 mm. Cu plus 0.5 mm. Al, and 0.5 mm. Cu plus 0.5 mm. Al. The fields measured 10 by 10 cm. The distance was 50 cm. The roentgen apparatus delivered 130 kv. (peak) and 5 ma. The stomach was filled before each irradiation with a barium sulfate suspension to localize and distend this organ adequately and to increase the amount of secondary radiation. Series 1 consisting of 3 dogs received the treatment shown in Table 1.

TABLE I
DOSAGE
(Series 1)

5 consecutive weeks	15 r daily
4 consecutive weeks	30 r daily
2 consecutive weeks	60 r daily
1 week rest period	
5 consecutive weeks	60 r daily
1 week rest period	
1 week	60 r daily
1 week rest period	
1 week	60 r daily
1 week rest period	
1 week	120 r daily
1 week rest period	
1 week	120 r daily

A total of 4,875 r was given during twenty-five weeks. The dogs remained in good health and were sacrificed sixteen months after the start of the experiment by an intravenous injection of 30 cc. of a 4 per cent formaldehyde solution.

The other 4 dogs composing the second series received on each day 300 r for four successive weeks (total 6,000 r). After an initial gain of 2 to 2.5 kg. the dogs lost progressively in body weight until they reached approximately 50 per cent of their maximum weight toward the end of the experiment. One of the 4 dogs died acutely at the end of the eighth week following the aspiration of barium sulfate suspension into the lungs. The other 3 dogs of this series died nine, thirteen, and sixteen weeks, re-

spectively, after the start of the experiment as the result of a perforated gastric ulcer. The dogs were highly emaciated at this time and had an atrophic and epilated skin over the gastric region. There were ulcers of the skin present in 2 dogs.

HEMATIC DATA

Hematological studies were made on the dogs of the first series at intervals of two weeks during the first two months and at intervals of one month thereafter. Blood examinations were performed on the dogs of the second series once every week throughout the entire experimental period.

TABLE II

HEMATIC CHANGES IN DOG IRRADIATED DURING 25 WEEKS WITH DOSES RANGING FROM 15 TO 120 r

Weeks	Hemoglobin	Erythrocytes	Leukocytes
0	14.2	6.15	11.7
2	15.4	6.46	9.2
4	14.9	6.88	11.5
6	15.6	7.05	11.0
10	17.2	7.45	10.6
14	11.4	5.34	14.3
18	11.4	4.96	11.2
28	17.2	8.31	11.9
30	14.5	8.32	10.5
34	15.6	6.46	7.7
50	14.2	5.51	9.5

Following an initial mild increase in the number of erythrocytes the dogs of the first series showed at the end of the twenty-fifth week a definite decrease amounting to 15 to 20 per cent of the original value. The hemoglobin and hematocrit values underwent similar fluctuations, whereas the number of leukocytes remained within normal limits. One month after the cessation of the roentgen treatments the number of erythrocytes had recovered and surpassed by approximately 20 per cent the original level where it remained for about two months before it dropped gradually back to pretreatment values. Table II shows the hematic changes in 1 dog.

The erythrocytes of the dogs of the second series remained within normal limits during the first two to three months and then decreased in number to a moderate to marked degree, depending upon the length of the survival period. This numerical reduction of the erythrocytes was usually preceded by a mild to marked drop in their hemoglobin content which exceeded in degree that of the number of cells and reached in one instance more than 50 per cent of the original value giving a color index of below 1. The number of leukocytes fluctuated irregularly in the different animals. There were no appreciable changes present in 2 dogs; a considerable decrease in number associated with the appearance of immature cell forms was noted in a third dog, while a marked elevation of the number of leukocytes up to 55,000 was found in the fourth dog. The number of reticulocytes did not vary significantly during the first month of treatment. Table III presents the blood findings of 1 of these dogs.

TABLE III

HEMATIC REACTIONS IN DOG 356 IRRADIATED OVER THE GASTRIC REGION WITH 20×300 r

Days	Hemoglobin	Erythrocytes	Leukocytes	Reticulocytes
0	16.2	6.65	9.9	0.4
6	14.3	5.79	11.25	0.4
15	14.5	6.1	14.9	0.2
26	16.0	7.3	11.6	0.4
33	14.2	6.76	17.8	
40	12.0	6.26	17.2	
47	13.2	6.53	17.2	
54	12.9	6.81	21.6	
61	13.9	6.95	23.6	
68	13.1	6.01	39.4	
75	12.2	5.59	36.6	
82	10.1	4.65	36.3	
89	9.0	4.35	34.0	
96	7.8	3.45	55.4	
103	6.5	3.47	33.4	
113	Death from perforated gastric ulcer			

ANATOMIC DATA

The postmortem examination of the 3 dogs composing the first series did not reveal any abnormal significant gross changes of the internal organs. The dogs of the sec-

ond series revealed, on the other hand, a definitely thickened and edematous gastric and duodenal wall. There was a small opening in the gastric wall in the prepyloric region of the greater curvature in 3 dogs. The stomachs showed here shallow mucosal defects measuring about 2.5 to 4 cm. in diameter and having a central, narrow, cone-shaped crater penetrating the entire wall. The edges of the ulcers were sharply cut out. A coffee-ground colored mucus was attached to the surrounding edematous mucosa. The abdominal cavity contained a small amount of brownish turbid fluid. All other organs were normal with the exception of scattered pulmonary hemorrhages and the presence of white matter in the bronchi of the dog which died acutely after the aspiration of barium sulfate suspension into the lung.

The stomachs as well as most of the other internal organs (duodenum, colon, pancreas, liver, lung, aorta, heart, pulmonary artery, adrenals) of the dogs of the first series were histologically normal. The liver of 1 dog revealed, however, a considerable fatty degeneration of the liver cells associated with an appreciable increase of the periportal and intralobular connective tissue. Small groups of intact liver cells were found scattered along the connective tissue septa. The reticulum cells of the spleens contained in 2 dogs large amounts of an amorphous brown pigment. The bone marrow of the 3 dogs consisted of a loose fat tissue containing an irregular scattering of strands and nests of immature myeloid cells. The reticulum cells in the bone marrow of 1 dog were filled in part with a brown amorphous pigment.

The histological changes found in the organs of the dogs of the second series contrasted sharply with these relatively insignificant findings. The epidermis of the irradiated abdominal skin was in most places definitely atrophic, and showed some hyperplastic proliferative extensions in a few areas. The ulcerative epidermal defects were covered with a leukocytic, necrotic mass loosely attached to a fibrous and hyaline subcutaneous tissue. The sweat and sebaceous glands and the hair follicle were definitely atrophic or had disappeared entirely, leaving small whirl-like scars. Numerous small follicular cysts lined by concentrically arranged layers of a flat epithelium were found in 1 dog. The cutaneous and subcutaneous vessels were often ectatic. Some of the arteries had swollen walls. The underlying muscle tissue of the abdominal wall showed focal waxy degenerations associated with a proliferation of the muscle cell nuclei and, in places, with calcification of the necrotic muscle cells.

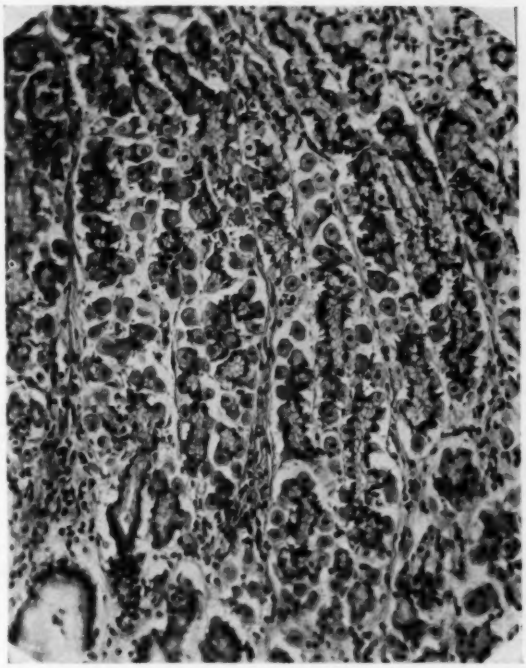

Fig. 1. Mucosa of the gastric fundus showing a degeneration and disappearance of the chief cells and a predominance of the parietal cells.

Stomach: The mucosa of the cardial portion was normal. The mucosa of the fundus was normal in one dog, and showed an extensive degeneration or loss of the chief cells, preservation of the parietal cells, and scattered focal necrosis of the superficial columnar cells in a second dog. The submucosa and muscularis were normal in these 2 dogs. Similar mucosal changes were present in the fundus region of a third dog, but they were accompanied by a fibrotic

FIG. 2. Ulcer in the prepyloric region covered with a thick leukocytic exudate.

submucosa and hyaline degenerated muscularis which had in places a bluish cast suggesting a beginning calcification. In a fourth dog such lesions were combined with the presence of cystic glandular formations filled with a mucoid material (Fig. 1). The submucosa was highly edematous. In the neighborhood of the ulcerative defects located in the prepyloric region of the fundus the submucosa was markedly swollen and in places hyaline. There was moreover a diffuse and moderate leukocytic infiltration present (Fig. 2). The walls of the vessels were swollen and homogeneous (Fig. 3). Necrotic and inflammatory changes extended into the muscularis and subserosa, in which the lymphatics and veins were highly dilated and sometimes lined by huge, distorted endothelial cells. In one area of the prepyloric region of 1 dog there was a complete disappearance of the epithelial elements in the mucosa leaving a collapsed connective tissue framework which covered an edematous congested submucosa containing vessels with swollen and hyaline walls. The mucosa of the pylorus exhibited an atrophic and, in places, cystic mucosa.

Duodenum: Superficial mucosal necrosis and occasional glandular cyst formation were observed in 2 dogs.

Spleen: Much amorphous brown pigment was noted in the reticulum cells.

Kidney: Some of the small arteries and arterioles of 2 dogs had swollen and edematous walls and a narrow subendothelial hyaline zone. In 1 of these 2 dogs there was an increase of the interstitial connective tissue which was infiltrated with lymphocytes and was transformed in places into a hyaline network. Numerous glomeruli had thickened hyaline capillary walls.

Testes: The spermatogenic epithelium in the testes of 3 dogs was markedly degenerated, leaving often only a single layer of Sertoli's cells or a mixture of Sertoli's cells with spermatogonia. Some tubules contained spermatid giant cells. The testes of the fourth dog were normal.

Bone Marrow: A dense myeloid bone marrow was present in 2 dogs, while a loose fat tissue containing a moderate admixture of myeloid tissue was found in the other 2 dogs.

Liver: The livers were edematous and hyperemic. There was a narrow subcapsular zone of necrosis of liver cells present in 1

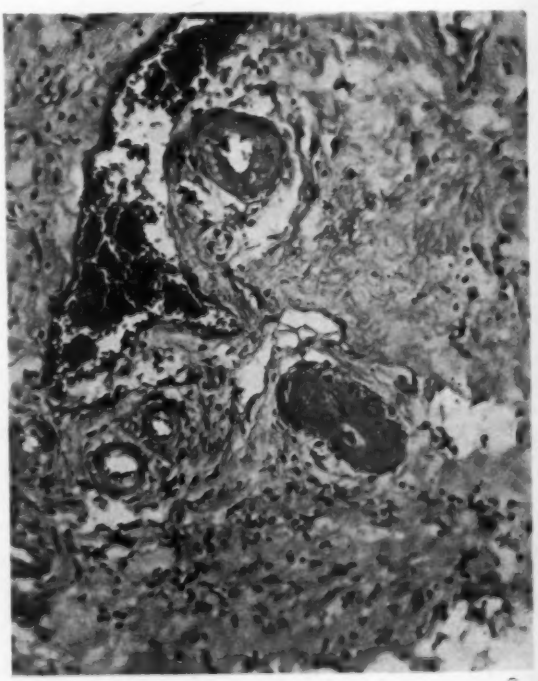

FIG. 3. Albuminoid swelling and necrosis of the vascular walls in the subserosa beneath the ulcerative defects.

dog. The liver cells in the demarcation zone were small and hyperchromatic. Numerous brown or brownish-gray pigmented phagocytic cells were noted in the tissue around the central veins and in the periportal tissue.

Aorta: A small intimal coagulation necrosis was found in the descending aorta of 1 dog. The aorta of a second dog revealed a marked medial mucoid imbibition in one sector and an almost complete fibrosis and hyalinization of the media involving approximately one-half of the circumference in a second sector. There were a few foci of medial muscular degeneration in the aorta of a third dog.

The following organs were histologically normal: lung, heart, pancreas, adrenal, lymph nodes, small and large intestine, epididymis, bladder, and brain.

COMMENT

The hematic and organic reactions recorded indicate that a prolonged irradiation of the stomach with small doses of roentgen rays produces an anemia of the secondary type and not one of the pernicious variety, which would have resulted if the treatment given had interfered with the production of the "intrinsic factor" generated by the gastric mucosa, according to Castle. The absence of any significant anatomical lesions in the gastric mucosa of the dogs of Series 1 makes it unlikely that the actinic energy administered to the stomach elicited here any specific and permanent secretory damage, especially as the transitory anemic response reverted rapidly after the cessation of the treatment to a transient erythrocytotic reaction. The secondary anemia noted in the dogs of the second series during the latter part of the experimental period is evidently attributable to a continued loss of blood from the ulcerated gastric mucosa. The changes in the gastric mucosa of these animals were also responsible for the severe loss of weight sustained by them as the result of loss of appetite and associated digestive disturbances.

The chief cells of the gastric mucosa are, according to the observations made, definitely more sensitive to the action of the roentgen rays than any other cellular element of the gastric mucosa. The parietal cells appear to be particularly resistant, while the surface cells and glandular epithelium of the cardial and pyloric regions occupy an intermediate position in this respect. The mucosal lesions recorded, such as glandular mucoid cysts, atrophy of epithelial cells with bizarre distortions and swelling, interglandular edema and fibrosis, submucosal edema, congestion, fibrosis, hyalinization, and leukocytic infiltration associated with vascular dilatation and arterial edema and hyalinization, are similar to those reported before by Warren, and Warren and Friedman; Delbet, Herrenschmidt and Mocquot; Regaud, Nogier and Lacassagne, and others. They are fundamentally of the same type and origin as those which were seen by us in the intestinal mucosa of 13 dogs one to three weeks after the administration of 1,200 to 1,500 r over the abdomen for the production of a traumatic shock, as well as those elicited in the mucosa of the urinary bladder of 22 dogs by the administration of 1,200 r (Hueper, Fisher, Carvajal-Forero and Thompson).

The occurrence of hemangiectases and lymphangiectases in the submucosa which was lined by swollen, protruding endothelial cells confirms observations previously made by Dawson; Ivy, McCarthy and Orndoff; Kolodny, and Lazarus-Barlow. The hyalinizing and sclerosing arterial lesions present in the region and especially the floor of the gastric ulcers are similar in type and location to those noted in the ulcerated stomach of dogs subjected to histamine shock (Hueper and Ichniowski) as well as to those found in the small arteries of the thickened and inflamed renal capsules of dogs with cellophane perinephritis. These arterial changes are not the cause of the gastric ulcers and are not of specific actinic origin, but secondary to the necrotizing and sclerosing tissue changes caused

in the gastric wall by the roentgen rays (Engelstad; Schürch and Uehlinger).

While it is possible that the degenerative and sclerosing intimal and medial lesions seen in the descending aorta of 3 dogs of the second series may have an actinic genesis, the appearance of similar arterial and arteriolar changes in the kidneys of 2 dogs as well as the extensive atrophy of the spermatogenic epithelium of 3 dogs of this series makes it more likely that they are nonspecific sequelae of metabolic disturbances elicited by the roentgen irradiation during the latter part of the experimental period.

SUMMARY

1. Roentgen rays given in doses of 15 to 120 r up to a total of 4,875 r within twenty-five weeks over the gastric region of dogs cause only minor anatomic changes in the gastric mucosa, and a transitory and moderate anemia of the secondary type which is followed by an erythrocytotic phase after the cessation of the actinic treatment.

2. Roentgen rays administered in doses of 300 r up to a total of 6,000 r within four weeks produce a marked loss in body weight, a moderate to severe secondary anemia, and perforating gastric ulcers at the end of this period.

3. There is no evidence that roentgen rays administered in the above manner have any injurious effect upon the production of the "intrinsic factor" of Castle.

4. The chief cells of the gastric mucosa are most sensitive to the action of the actinic energy, while the parietal cells appear to be most resistant.

113 West 18th St.,
New York, N. Y.

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SOME COMPARATIVE STUDIES IN THE ARRANGEMENT OF RADIATION BEAMS

THREE IDENTICAL CIRCULAR BEAMS DISPOSED SYMMETRICALLY

By C. W. WILSON, M.Sc., PH.D., F.INST.P.
Physics Department, Westminster Hospital
LONDON, ENGLAND

IN RECENT years considerable attention has been given to the total distributions of radiation that result from various combinations of a number of radiation beams,[2,3,4,10] and special methods have been devised for the detailed study of such distributions throughout the whole volume of irradiated tissues.[5,7,8,9] As a result of the investigations into these matters it has been shown that, if optimum and homogeneous conditions of dosage are to be achieved, it is essential that the positions and the directions of the individual beams be arranged by a very careful reference to the shape of the beams as expressed by their dose contours. In many cases this reference indicates that the beams should be directed not at the tumor itself but at some other point or points at a greater depth in the tissues,[2,3,10] a result which is contrary to customary radiotherapeutic practice.

This article describes an investigation into the effect of various factors upon the total radiation distribution due to three identical circular beams of radiation arranged symmetrically and inclined at a common angle to a basic plane. It is assumed that the same dose is delivered by each beam. An example of such an arrangement has been discussed by Lamerton and Mayneord[3] for three roentgen-ray beams but the present study is of a more general character. A number of beams are considered, each inclined at various angles to the basic plane and the effect of changing the spacing of the beam centers is examined in some detail. This investigation, which forms part of a general study of the combination of radiation beams, is principally concerned with the gamma-ray beams from radium mass units but some cases of roentgen-ray beams have been considered also.

The use of a symmetrical three field technique in the irradiation of a breast has been commented on[3] and at Westminister Hospital such a technique has proved of value also in the roentgen-ray and gamma-ray irradiation of certain brain tumors, metastatic and other glandular masses, and in the treatment of lesions near or in the skin surface which also extend to a considerable depth.

RADIATION BEAMS

The various beams considered are as follows:

1. Gamma-ray beam of Westminster Hospital 4 gm. radium unit.[1] Field 3.5 cm. diam: F.S.D. = 8.0 cm.
2. Gamma-ray beam of Radium Beam Therapy Research 5 gm. radium unit.[12] Field 5.0 cm. diam: F.S.D. = 8.3 cm.
3. Gamma-ray beam of Westminster Hospital 4 gm. radium unit.[1] Field 9.0 cm. diam: F.S.D. = 8.0 cm.
4. Roentgen-ray beam, 190 kv. Thoraeus filter. H.V.L. = 1.8 mm. Cu. Field 5.0 cm. diam: F.S.D. = 50 cm.
5. Roentgen-ray beam, 190 kv. Thoraeus filter. H.V.L. = 1.8 mm. Cu. Field 10.0 cm. diam: F.S.D. = 50 cm.

The dose contours of the gamma-ray beams have been published.[1,12] Those of the roentgen-ray beams are shown in Figure 1. The focus-skin distance of the Radium Beam Therapy Research 5 gm. unit (8.3 cm.) is little different from that of the Westminster Hospital 4 gm. unit (8.0 cm.) so that we may consider the former as a beam of area between the two areas of the Westminster Hospital unit but otherwise comparable.

It is assumed throughout that conditions of scatter and absorption, in the practical application of the beams to the patient, are such that the dose contours, which are measured in complete phantoms, are valid. In the case of the gamma-ray beams it is unlikely that any large errors will arise

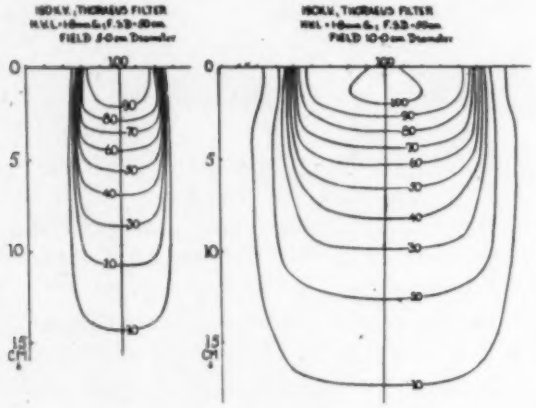


FIG. 1. Dose contours of roentgen-ray beams.

because of these factors, but for roentgen-ray beams it would be essential to add suitable scattering media (bolus bags, wax, etc.) to fill any gaps that may be produced through the arrangement of the beams.

DISPOSITION OF THE BEAMS

The symmetrical disposition of the three fields may be illustrated generally as in Figure 2. In effect the surfaces of the fields are applied to the sides *ABD*, *ADC* or *BDC* of a tetrahedron *ABCD* which is shown in plan. The central rays of each beam are directed through symmetrically disposed points R_1, R_2 and R_3. The tissues to be irradiated thus lie beneath the sides of the tetrahedron, the beams being directed through the tissues in directions such as R_2T shown in the section drawn through the plane *BDF* (Fig. 2).

For each of the beams described above, the dosage conditions and the factors which govern them, were examined for specific values of the angle θ between any one of the sides of the tetrahedron and the basic plane. The values taken were 15°, 30°, 60° and 90°. When $\theta = 90°$ the fields are no longer applied to the sides of a tetrahedron but are symmetrically situated around a circle. The latter arrangement is typical of methods often used for the irradiation of a whole limb.

DISTRIBUTION OF DOSAGE IN THE PLANE OF ENTRY

It is of interest to examine how the distribution of dosage in the plane $O\,R_1\,R_2\,R_3$ depends on the angle of slope θ and the

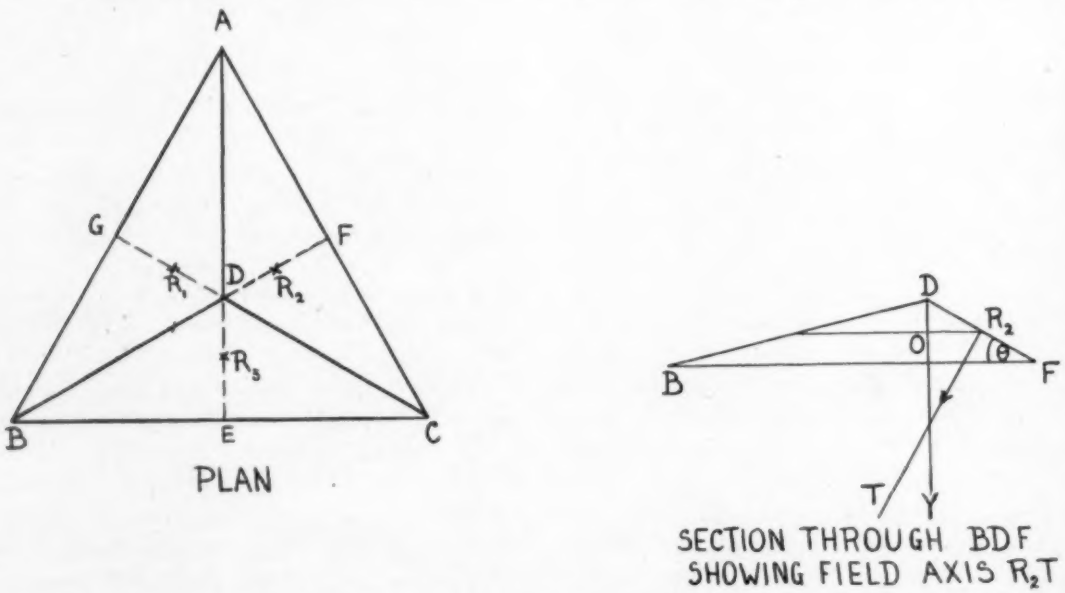


FIG. 2. Illustrating the geometrical features of the arrangement of three radiation beams.

radius of separation of the fields R_2O, especially with regard to the homogeneity of the distribution. The plane $O\,R_1\,R_2\,R_3$ may be referred to as the "plane of entry" of the beams and for moderate values of θ it would coincide approximately with the skin surface around which the fields are arranged. When $\theta = 90°$ the plane of entry becomes the central plane of the tissues which are encompassed by the three fields and it carries the maximum dosage values of the irradiated volume.

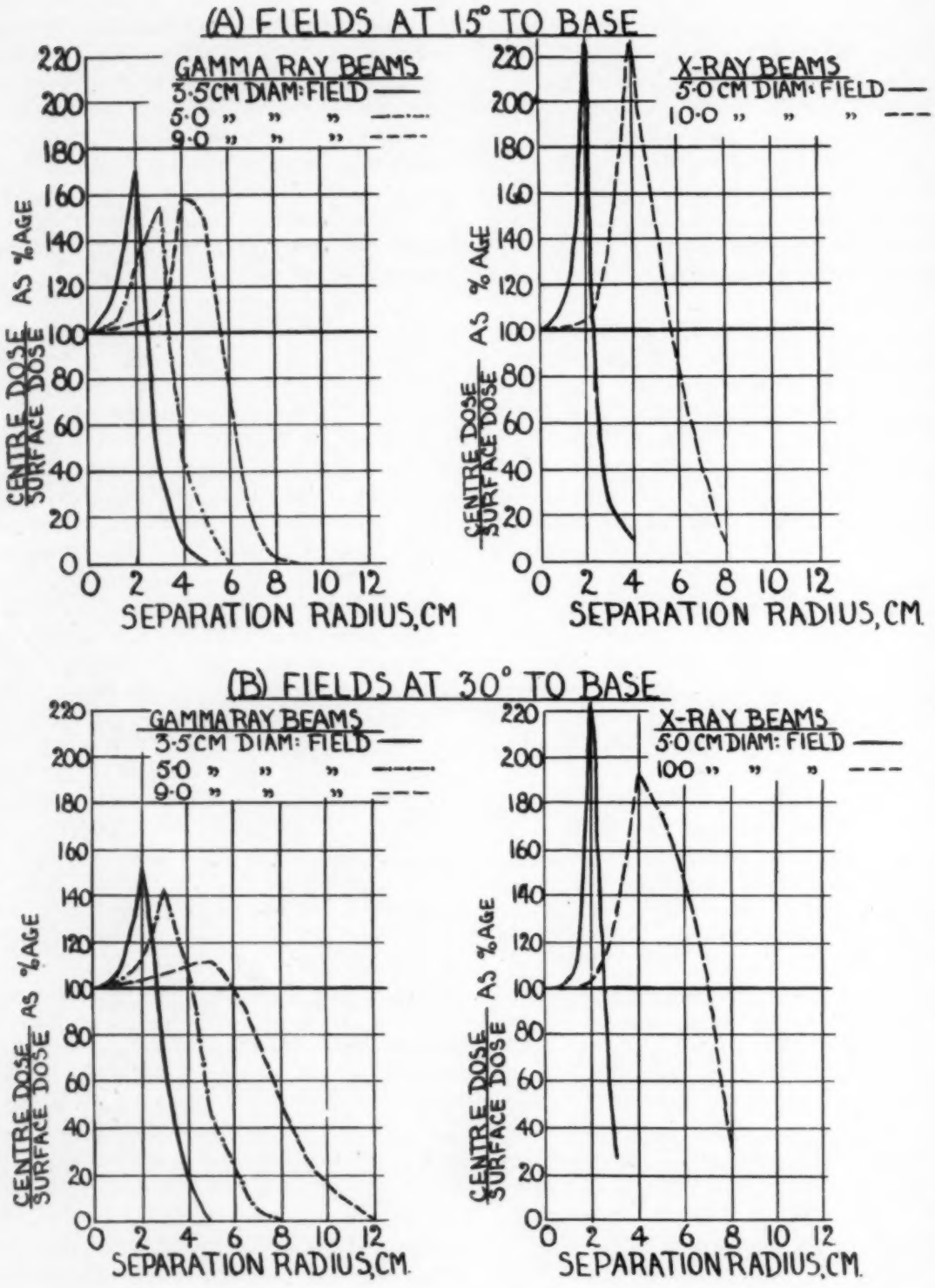
A convenient measure of the degree of homogeneity of dosage in the plane of entry is the ratio of the total dose at the center point O to that at the points of entry R_1, R_2, or R_3, of any of the beams. The latter we shall refer to as the "surface dose." The dose at R_1, R_2 and R_3 is the same because of the symmetry of the arrangement and the "center dose" at O is made up of three equal parts, one part due to each beam. The greatest homogeneity exists in the plane of entry when the value of the ratio center dose to surface dose is unity; a more detailed examination of the total distribution in this plane shows that the dose at any other point is seldom greater than it is at R_1, R_2, R_3, and O.

The results obtained from the examination are shown graphically in Figure 3. The curves show how the ratio (expressed as a percentage) of the center dose and surface dose depends upon the separation R_2O of the fields; a set of curves is shown for each of the θ values considered.

A number of useful points emerge from a consideration of these curves. First, it may be seen that certain radii of separation, in particular instances, give rise to a central dose greatly in excess of the surface dose, so that a central "hot-spot" exists. In general the severity of the "hot-spot" is greatest for the smaller angles of slope and smallest fields and least for the greater angles of slope and largest fields. Further, it is seen that in those cases where a severe central "hot-spot" does occur for a certain radius of separation, the rate of change of the ratio, with alteration of the radius, is very great. It follows that slight alterations in the values of the radius will produce marked changes in the degree of homogeneity in the plane of entry. For these reasons, if it is desired that homogeneity should exist in this plane, considerable care must be exercised in using this technique, particularly if small fields at angles of 15° to 30° to the base are used; those values of radius of separation for which the central "hot-spots" occur most certainly should be avoided. The greater aggravation of these conditions which is seen to exist in the case of the roentgen-ray beams, is due to the fact that these are more sharply defined than are the gamma-ray beams.

Figure 3, *B*, *C* and *D*, shows that for any angle of slope equal to or greater than 30°, a severe central "hot-spot" does not arise in the case of the 9.0 cm. diameter gamma-ray beam for any value of the radius of separation. It follows that in using this field one has more latitude but another disadvantage arises, namely, that for practical values of the separation radius, the center dose is always less than the surface dose for the larger angles of slope.

The case when the fields are disposed around a circle (Fig. 3 *D*) is of interest, representing, as it does, a technique that might be employed in the treatment of disease located fairly centrally within a limb, a tumor of bone, for instance. It is seen that for the gamma-ray beams the ratio does not greatly exceed unity whatever the size of field or whatever the radius of separation. Indeed, with the 5 cm. and 9.0 cm. diameter fields the center dose is always less than the surface dose so that the technique does not permit one to deliver a center dose in excess of the surface dose. When the roentgen-ray beams are arranged in this manner it is possible, with the 5 cm. diameter field, to produce a dose at the center in considerable excess of the surface dose (up to 170 per cent for 4.0 cm. separation radius), but with the 10 cm. diameter field only an added 10 per cent or so is ever achieved. The curve shows, in fact, that the three 10 cm. diameter roent-


(A) FIELDS AT 15° TO BASE
GAMMA RAY BEAMS
3·5 CM DIAM: FIELD
5·0 " " "
9·0 " " "
X-RAY BEAMS
5·0 CM DIAM: FIELD
10·0 " " "
CENTRE DOSE / SURFACE DOSE AS %AGE
SEPARATION RADIUS, CM
(B) FIELDS AT 30° TO BASE
GAMMA RAY BEAMS
3·5 CM DIAM: FIELD
5·0 " " "
9·0 " " "
X-RAY BEAMS
5·0 CM DIAM: FIELD
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CENTRE DOSE / SURFACE DOSE AS %AGE
SEPARATION RADIUS, CM

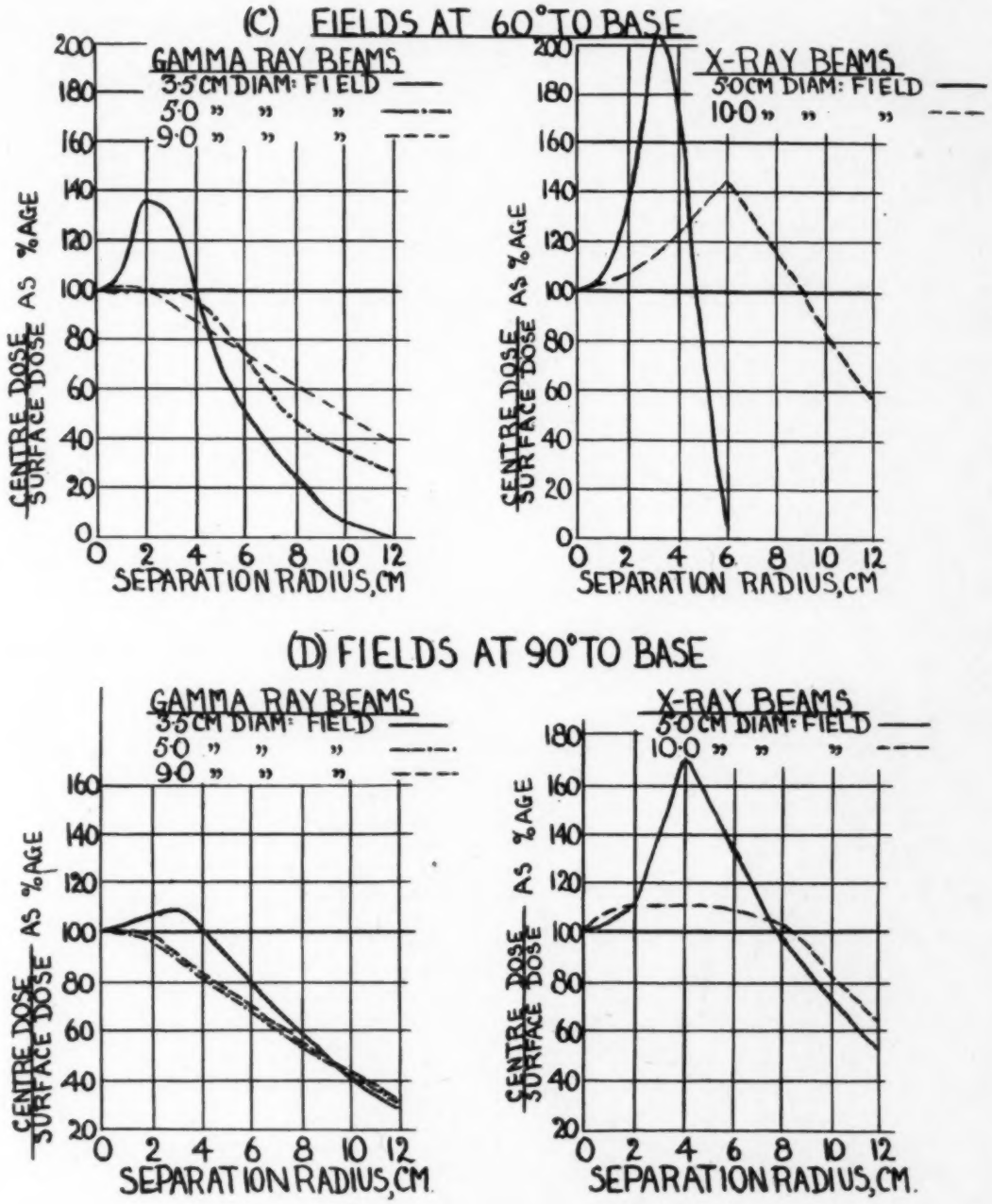
(C) FIELDS AT 60° TO BASE
GAMMA RAY BEAMS
3·5 CM DIAM: FIELD
5·0 " " "
9·0 " " "
X-RAY BEAMS
5·0 CM DIAM: FIELD
10·0 " " "
CENTRE DOSE / SURFACE DOSE AS %AGE
SEPARATION RADIUS, CM
(D) FIELDS AT 90° TO BASE
GAMMA RAY BEAMS
3·5 CM DIAM: FIELD
5·0 " " "
9·0 " " "
X-RAY BEAMS
5·0 CM DIAM: FIELD
10·0 " " "
CENTRE DOSE / SURFACE DOSE AS %AGE
SEPARATION RADIUS, CM.

FIG. 3(*A*)(*B*)(*C*)(*D*). Curves showing the effect of the separation of the beams upon the degree of homogeneity in the plane of entry.

gen-ray beams, so arranged around a circle, give approximate homogeneity for all radii of separation from 0 to 9 cm.

EFFECTIVE DEPTH DOSES

Further interesting data concerning the dosage possibilities of the three field tech-

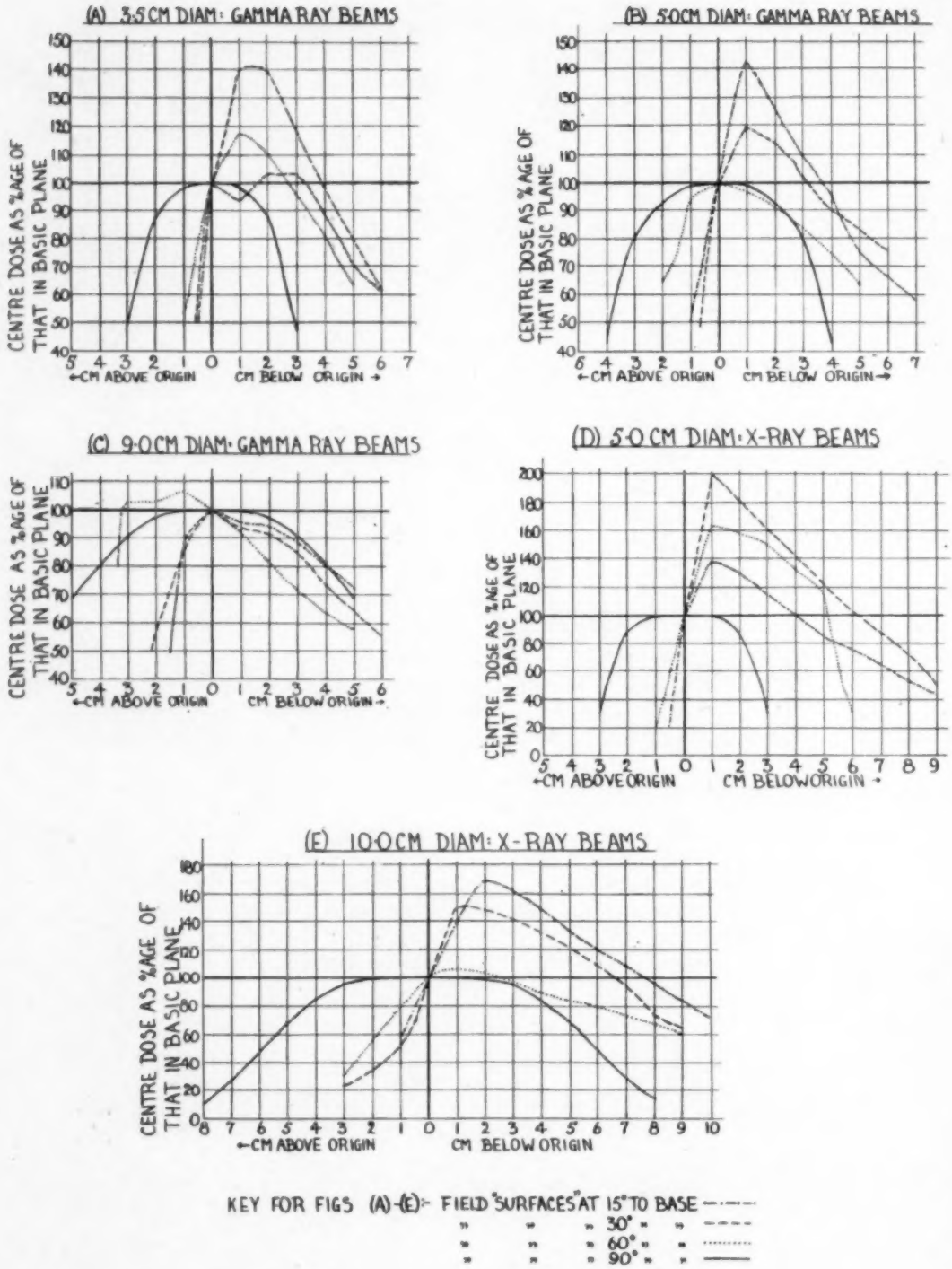
(A) 3·5 CM DIAM: GAMMA RAY BEAMS
(B) 5·0 CM DIAM: GAMMA RAY BEAMS
(C) 9·0 CM DIAM: GAMMA RAY BEAMS
(D) 5·0 CM DIAM: X-RAY BEAMS
(E) 10·0 CM DIAM: X-RAY BEAMS
CENTRE DOSE AS %AGE OF THAT IN BASIC PLANE
←CM ABOVE ORIGIN
CM BELOW ORIGIN →
KEY FOR FIGS (A)-(E):- FIELD SURFACES AT 15° TO BASE
" " " 30° " "
" " " 60° " "
" " " 90° " "

FIG. 4. Curves showing the variation of total depth dose with distance from the plane of entry (homogeneity in the plane of entry pre-arranged).

nique may be obtained by a consideration of the "total effective depth doses." For the purpose it was decided to consider those cases where maximum homogeneity exists in the plane of entry. Therefore we have considered the depth doses for the various fields and angles of slope, in each case adjusting the radius of separation of the beam centers to that value for which the center dose to surface dose ratio is equal to 100 per cent. Under these conditions the maximum possible area in the plane of entry is irradiated with the optimum degree of uniformity.

A valuable picture of the depth dosage available from the various arrangements is obtained by consideration of the variation of the dose along the central axis of the three field system, i.e., along the line *DOY* (Fig. 2). For this purpose we have determined, in each case, the total dose at points above and below *O*, and have plotted the values (expressed as a percentage of the dose at *O*) against the distance from *O*. The results thus obtained are shown in Figure 4 which gives a composite picture of the variation of total percentage depth dose with distance from *O*. The conditions examined thus appertain to the question of irradiating, uniformly, a block of tissue extending down from, and including, the skin surface to which the fields are applied. With the exception of the case where $\theta = 90°$, they are conditions, therefore, which could arise in the irradiation of a glandular mass, particularly if ulcerating, or to other surface lesions which have invaded to some depth.

It is seen from Figure 4 that, with the exception of the specific case where the fields are arranged around a circle, the curves do not show any particular trend or regular behavior which could be related to change in the angle of slope or size of field. Indeed they afford a further striking example of the necessity of examining dosage conditions in irradiation techniques, in relation to the dose contours of the beams, before one can be sure of the distribution that will result.

In each case where the three fields are placed around a circle it is obvious that the dosage is distributed symmetrically on either side of the central plane containing the beam axes. It is seen from Figure 4 that at the distance from the central plane which corresponds to the geometrical edge of the beams the dosage value is only 60 to 70 per cent of the central dose for the roentgen-ray beams and 75 to 95 per cent for the gamma-ray beams.

The curves of Figure 4 show also, that in many cases, the total percentage depth dose may reach values considerably in excess of 100 per cent and generally these values are at depths of about 1 to 2 cm. below *O*. The change in dose with depth below *O* is consequently relatively rapid in these cases for the first 1 or 2 cm., so that adjustment of the tissues (more especially the skin surface) in relation to the fields (or vice versa) obviously must be very critical. For example, when the 3.5 cm. diameter gamma-ray beams are at 30° to the basic plane (Fig. 4*A*) a displacement of the skin surface from *O*, to a point 1 cm. below, would change the dose to 140 per cent of its former value and doses for all points at a depth would be less than 100 per cent of the new skin dose. In all these cases, therefore, the total depth dose, as measured with respect to the skin dose, depends very critically upon the relation of the fields to the tissues—more so than is generally realized. Figure 4*D* shows this to be so especially in the case of the 5 cm. diameter roentgen-ray beam.

Figure 4*C* brings out an important point, namely, that no matter at what angle to the basic plane one decides to use the 9.0 cm. diameter gamma-ray beam, the dose at any point below *O* is never equal to, or in excess of, that at *O*. Thus, from the point of view of depth dosage the technique is not efficient for these beams.

From Figure 4*E* it is seen that the arrangement of three 10 cm. diameter roentgen-ray beams at 15° or 30° to the basic plane gives very efficient dosage conditions. Thus, at depths of 1 to 4 cm. below *O* a depth dose of 130 to 170 per cent is ob-

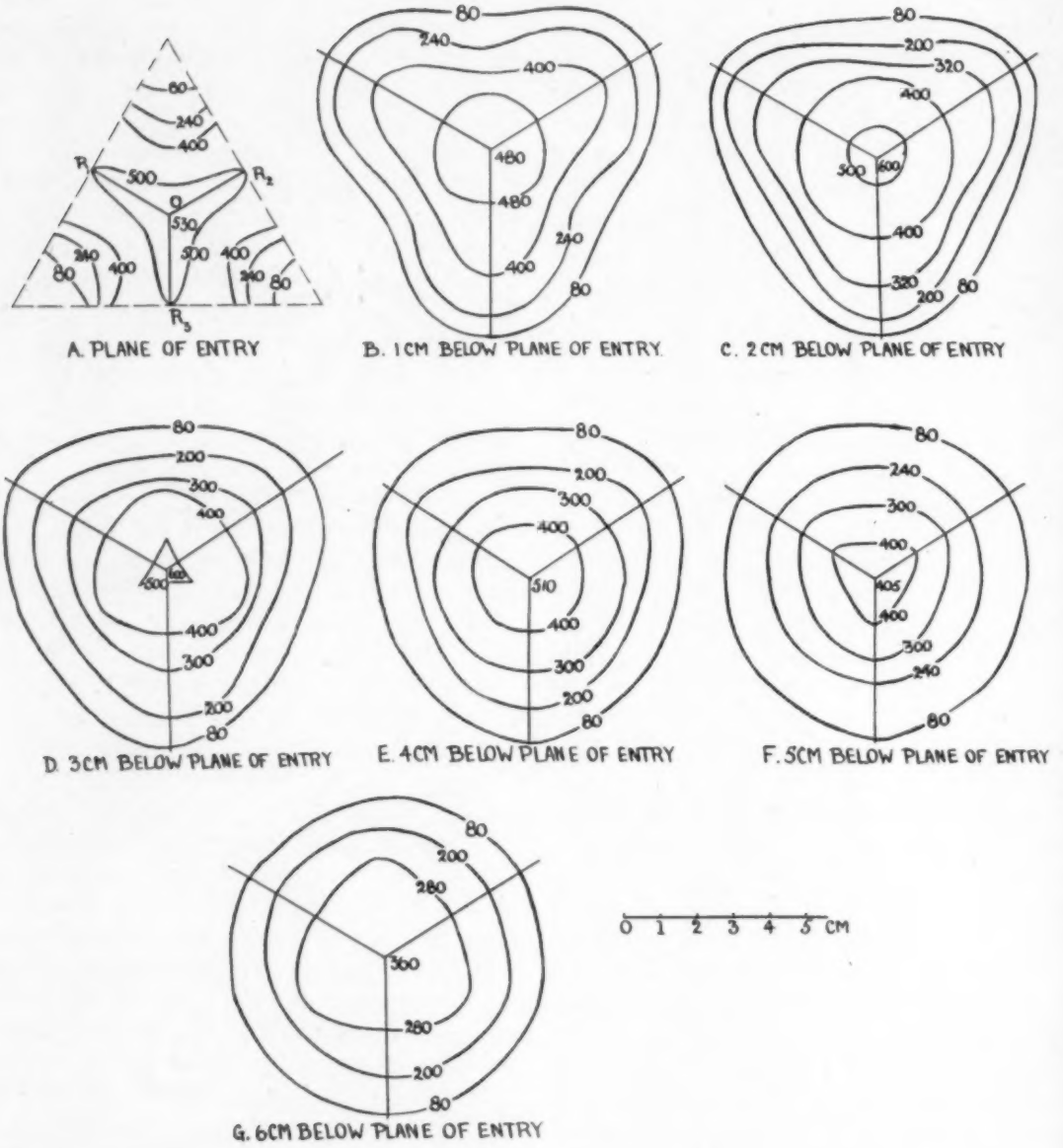
A. PLANE OF ENTRY
B. 1CM BELOW PLANE OF ENTRY
C. 2CM BELOW PLANE OF ENTRY
D. 3CM BELOW PLANE OF ENTRY
E. 4CM BELOW PLANE OF ENTRY
F. 5CM BELOW PLANE OF ENTRY
G. 6CM BELOW PLANE OF ENTRY
0 1 2 3 4 5 CM

FIG. 5. Dose contours showing the three-dimensional distribution of radiation for three 3.5 cm. diameter gamma-ray beams at 75° to the basic plane (i.e., $\theta = 15°$) and arranged to provide homogeneity in the plane of entry.

tained while the depth dose is still 100 per cent at 7 to 8 cm. depth. Angles of slope between 15° and 30° presumably will not be very different since the values for 15° and 30° run very close to one another. The values for $\theta = 60°$ are very similar to the results published by Lamerton and Mayneord[3] for this kind of arrangement; the slight differences are due to the fact that we have arranged our fields deliberately to give homogeneity in the plane of entry and not at a fixed radius of separation which is independent of homogeneity. In the latter case it is seen[3] that depths greater than 2.5 cm. receive a depth dose of less than 100 per cent.

THREE-DIMENSIONAL DISTRIBUTION OF RADIATION

A consideration of the depth dose curves

(Fig. 4*A*) for the gamma-ray beams of 3.5 cm.* diameter at 15° or 30° to the basic plane, suggests that these arrangements might be used profitably for the irradiation of disease in those cases where it is not too extensive in area, and is located near, or in the skin, from which it extends to depths from 3 to 5 cm. With this in mind, an examination of the complete three-dimensional distribution of radiation was made in these cases, in order to determine the total volume of tissue that would be adequately irradiated by the technique. For this examination any of the various methods may be used;[5,7,8] we preferred in this instance to use the geometrical method[8] of projecting dose contours followed by a summation of the fields due to the individual beams.

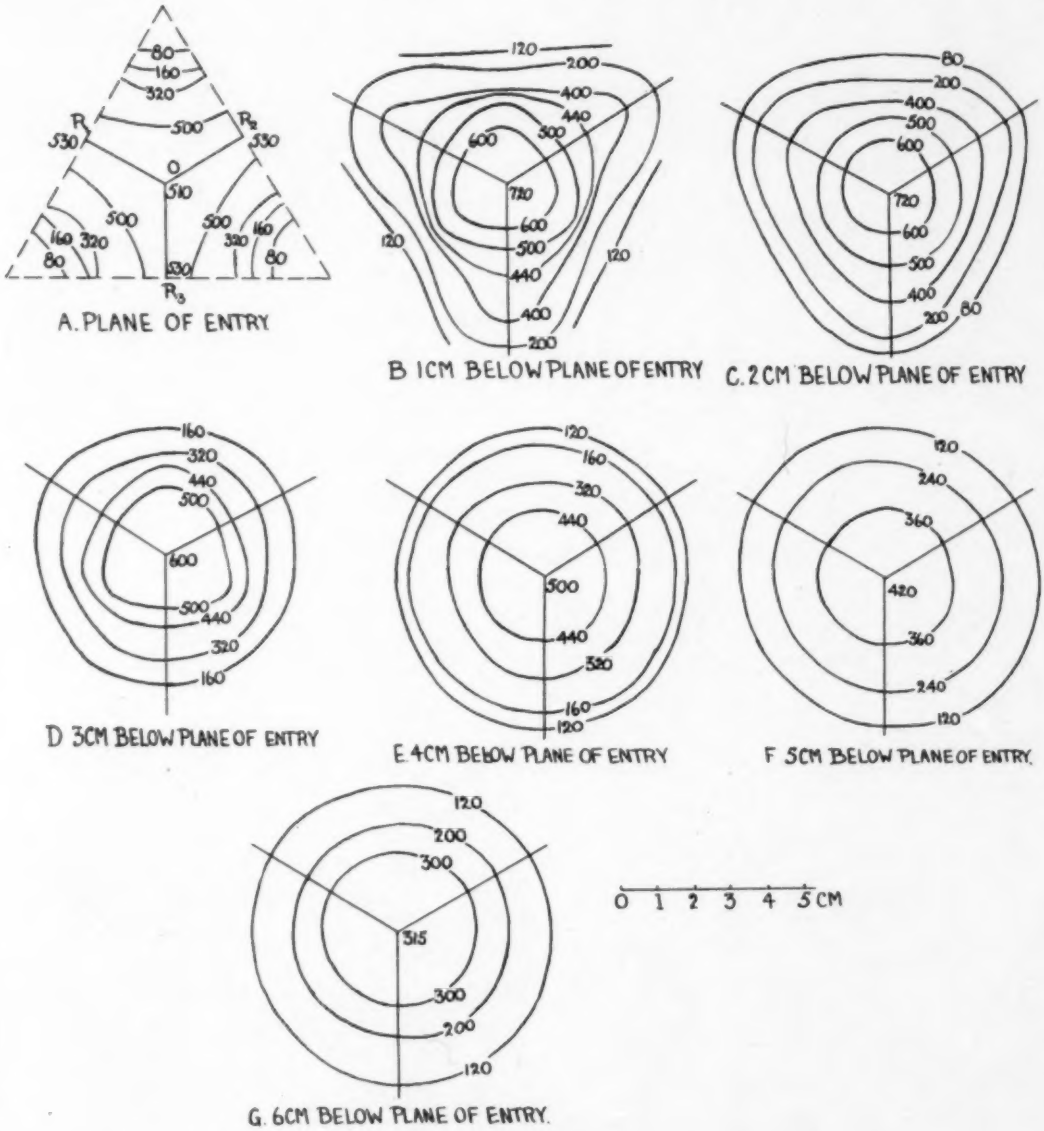
A. PLANE OF ENTRY
B 1CM BELOW PLANE OF ENTRY
C. 2CM BELOW PLANE OF ENTRY
D 3CM BELOW PLANE OF ENTRY
E 4CM BELOW PLANE OF ENTRY
F 5CM BELOW PLANE OF ENTRY
G. 6CM BELOW PLANE OF ENTRY
0 1 2 3 4 5 CM

FIG. 6. As Figure 5 but the beams are at 60° to the basic plane (i.e., $\theta = 30°$).

The results obtained are shown in Figure

* The same may be said with regard to the 5 cm. gamma ray but this is not available to us for therapy.

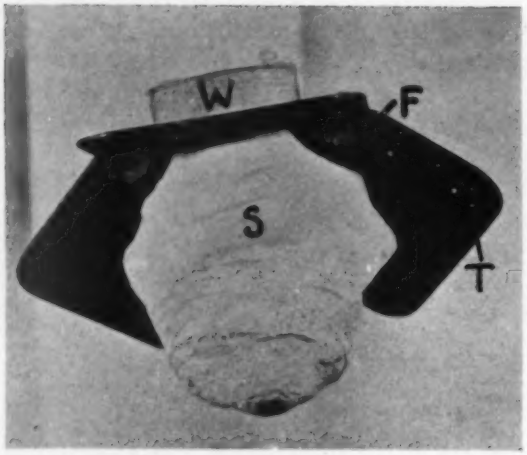

FIG. 7. Solid model of the 400 r isodose surface due to the arrangement of beams of Figure 6. The isodose surface is shown in its true relation to the surfaces to which the radium unit is applied.

5 ($\theta=15°$) and Figure 6 ($\theta=30°$) where they are expressed in terms of the dose contours in the plane of entry and in a series of planes parallel to, and at various distances below it. The dose numbers represent the dose obtained in roentgens when each of the three fields is applied for one hour, i.e., the dose delivered in three hours of total treatment. The three-dimensional distribution may be reconstructed by mounting the various planes at the correct intervals one above the other. Methods of such reconstruction which enable one to visualize the resultant isodose surfaces have been described by Mayneord and his coworkers.[3,5,6] One of these,[6] which produces a solid representation of a particular isodose surface, is to mount at the correct intervals, sheets of cardboard cut to the shape of the particular dose contour in each plane. The space between the sheets may then be filled with a suitable material (e.g., paraffin wax or plaster of paris) which is moulded to the surface of the cardboard framework to produce the isodose surface.

Figure 7 shows a model of the 400 r isodose surface obtained from the distributions of Figure 6. The surface *S* is shown mounted in its true relation to the surfaces to which the gamma-ray beams are applied; the latter are represented by a tetrahedron constructed of sheet brass and the position of one of the beams is indicated by a cylindrical wooden disk, *W*. Since the average dose in the plane of entry is of the order of 510 r it follows that the minimum dose received by the whole of the volume within the solid is practically an 80 per cent depth dose. Models of this kind are of great value in appreciating very exactly, the volume of tissue (and its shape) which is receiving a specified quantity of radiation.

APPLICATION OF RESULTS TO TELETHERAPY

It was considered that the distribution shown in Figures 5, 6 and 7 could be profitably used in actual therapy if arrangements were provided for the accurate placing and directing of the beams with respect to one another and to the site to be irradiated. The advantages of using such a predetermined radiation distribution have been pointed out before.[2,10] They are so important as to merit re-statement. Uniform irradiation is provided to encompass a precisely known volume of tissue and the dose

FIG. 8. Illustrating the use of a tetrahedral framework for the irradiation of a tumor of the parotid.

that will be delivered to the tissue is determined before treatment commences.

To provide for the application of the beams in the clinical practice of the technique, we have used a principle described elsewhere.[2] This is to provide a framework or "jig" which fits over the part to be irradiated and serves to place and direct the beams of radiation. Essentially the method provides a specific and known radiation distribution within which one places the tissues to be irradiated. In this case the framework is the tetrahedron of sheet brass illustrated in Figure 7. The brass (1 mm. thick), provides the secondary filter of the radium unit, which is maintained in the correct position and direction by the cylindrical wooden disk over which the aperture of the radium unit is fitted. Since the three fields are symmetrically disposed it is necessary to provide such a disk on one surface only of the tetrahedron; when the other fields are used the tetrahedron is rotated to the corresponding position. It is seen in Figure 4*A* that the dosage in the zone between the plane of entry and the apex of the tetrahedron falls very rapidly below the mean value in the plane of entry. In the brass tetrahedron used for therapy this zone is filled with columbia paste to prevent the tissues falling within it. The filling *F* may be observed in Figure 7.

In clinical use the framework is applied suitably to the region to be irradiated and skin markings along the edges of the base of the tetrahedron ensure that it is placed in the same position at each treatment. The provision of a firm and robust method of fixing the framework in position which is generally applicable, has caused some difficulty, and the problem is not yet solved to our complete satisfaction. For many sites, however, we have found that zinc oxide adhesive plaster, applied to the skin across the unused surfaces of the tetrahedron, is quite satisfactory. Figure 8 illustrates the use of a tetrahedron for the treatment of a tumor of the parotid. The radium unit shown in the figure is the Westminster Hospital 2 gm. unit[11] and not the 4 gm. unit to which reference has been made throughout this article. Data similar to those described have been determined for this unit also.

In conclusion, it should be pointed out that, in effect, the tetrahedral frameworks described, provide the therapist with a distribution of radiation that is known in the same sense that the distribution due to a single beam may be known. The difference is that the distribution beneath a tetrahedron is compounded from three beams and is very much more uniform than that provided by a single beam.

The author acknowledges the financial assistance given by the British Empire Cancer Campaign to the department in which this work was done.

SUMMARY

The total distribution of radiation resulting from the symmetrical combination of three circular radiation beams (roentgen or gamma rays) is examined and the effect of angulation, separation, and field size, is investigated.

Uniformity of dose in the plane of entry of the beams is shown to depend very critically upon the separation of the beams.

The depth doses and three-dimensional radiation distributions are examined for the case when uniformity exists in the plane of entry, in particular for the 3.5 cm. diameter gamma-ray beam.

A method of applying the results to clinical practice is described.

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PHOTOROENTGENOGRAPHIC TECHNIQUE AND DARK ROOM PROCEDURE USED AT THE ARMY RECRUITING AND INDUCTION STATION, NEW HAVEN, CONNECTICUT

By MAJOR CHARLES C. VERSTANDIG, *Medical Corps, Army of the United States, and* CORPORAL C. W. AINSWORTH, *Medical Department, Army of the United States*

PHOTOROENTGENOGRAPHIC technique and surveys are comparatively new. We have been quite fortunate in observing various methods of technique and feel that we may be able to offer a uniform procedure for photoroentgenographic technique which has proved to be quite satisfactory.

Upon arriving at the x-ray caption table the inductee's name, address, x-ray number, age, color, and weight are typed on his caption sheet.

NEW HAVEN ARMED	John Doe
FORCES INDUCTION	— — Street
DISTRICT	Waterbury, Conn.
17 December 1943	X-34708
LEFT	W-33-126

The caption sheet is made more legible with the aid of a sheet of carbon paper, the purpose of which is to make the writing on the caption as dark as possible; this in turn makes it much easier for the roentgenologist to read the information recorded on the roentgenogram.

The posteroanterior measurements of the chest in centimeters are taken during the inspiratory phase and the number recorded over the left scapular region of the inductee with a skin pencil. No roentgen examinations are done at this station without the thickness of the patient's chest first being measured in centimeters. The caliper is placed under the man's arm next to his chest with the immovable arm placed flat against the scapula. The movable member of the caliper is then placed so that it just touches the areolar tissue of the mammary gland of the individual. The measurement is taken on inspiration and recorded on the skin over the left scapular area.

On entering the roentgenographic room, the caption sheet is placed in the right caption holder, with the writing facing the examinee. The reason for this is to produce a true stereoscopic image in order to facilitate reading the caption sheet in the orthostereoscope. The left caption holder contains the name of the organization, address and date as well as the word "LEFT." The technician then places the inductee's chin on the chin rest and moves the fluorescent screen up or down to center the patient comfortably. The inductee is then asked to put his feet together, flat on the floor, and stand to midwidth of the film in order to obtain a perfect vertical alignment. The acromial processes are centered approximately 3 inches below the upper border of the cassette. The inductee's hands are placed on his iliac crests with the dorsa resting on the hips. The shoulders are then dropped into a normal position and the elbows flexed and forward. The tube is then turned in the "down" position, with the central beam passing directly through the center of the fluorescent screen. This is determined by the scale on the stand of the photoroentgen unit. When the scale numbers on this unit and the tube stand are the same, the central beam of the first exposure will pass directly through the center of the fluorescent screen. The technician then runs his hands along each side of the patient's chest to make sure that the patient is well within the fluorescent area. One technician then returns to the back of the photoroentgenographic unit and inserts a cassette, locks it in position, removes the guard, and places the film in the "down" position. This technician then steps behind a portable, mounted lead screen. The lead screen dimensions are 3 by 6 feet. The second technician goes to the control panel, steps behind another

mounted lead screen of the same dimension, looks through the lead glass window, notes the centimeter thickness recorded on the back of the inductee (in skin pencil) and sets the machine for the proper amount of kilovoltage. This technician then requests the man to "take in a deep breath, and hold it." The first exposure is then made. The tube and the film are then shifted up 4 inches; this complete shift is made by an electromagnetic control. The same technician then asks the man to "hold steady." A period of from eight to twelve seconds is allowed to elapse before the second exposure is made. The length of time between exposures serves a two-fold purpose: first, the tube is given a chance to stop vibrating, second the tube is given a chance to cool. If more time were taken between exposures there would be considerable motion on the film, because of the natural tendency for the selectee to breathe.

After the second exposure is made, the film guard is replaced in position with the "black topped" edge out, and the cassette holder is unlocked. The cassette is reversed, the film guard removed, the cassette holder placed in the down position and the next inductee is placed in position. When both sides of the cassette have been exposed, it is placed in the lead lined by-pass for developing.

This department believes a diagnostic roentgenogram must contain the following factors: (1) maximum of detail, (2) minimum of distortion, (3) medium of contrast, and (4) the proper amount of density.

The control stand is the General Electric Model KX-11. The tube is General Electric Model DX Coolidge Tube with a double focal spot of 2.2 and 4.2 millimeters square.

The unit also consists of a high voltage transformer. The rectifier is a four kenotron full wave type and delivers a pulsating direct current to the roentgen tube. We employ the 200 ma. and one-fifth second technique for chests measuring up to 28 cm. in thickness. For chests measuring over 28 cm. in thickness, the milliamperage is dropped to 150 ma., and the time is increased to two-fifths of a second.

For our chest photoroentgenograms we employ the 36 inch focal film distance without a grid.

This department adheres to an eighty man an hour output with the help of an auxiliary fan to keep the tube cool in addition to the blower attached to the tube head. We found that the rate of heat dissipation is greatly accelerated by the addition of this auxiliary fan which increases the air flow over the surface of the casing. It has been found that roentgenographing a greater number of men per hour results in heat input in excess of heat capacity, thereby increasing the temperature of the parts with consequent danger to the tube and the possibility of its destruction.

If the grid were used, less men would be roentgenographed per hour. We make an honest and concerted attempt to keep the heat units of the tube at a maximum of one-half million (kv., peak, $\times$ma. $\times$sec.) per thirty minutes.

The long axis of the focal spot of the tube is horizontal to the floor with the target end aligned to the sixth thoracic vertebra. This also aids in helping keep the roentgen tube cool.

The roentgenographic room is so arranged that the tube stand may be turned to a 90 degree angle for the purpose of taking 14 by 17 inch roentgenograms when indicated.

One member of the dark room "team" takes the film out of the lead lined by-pass, removes the guard from the cassette as well as the film and turns the guard around so that the white side is out. He then passes the exposed film on to the man who places it in the developing hangers, using the utmost caution to touch only the corners of the film. The first member of the team now reloads the cassettes and places the films in the film bin. To load a cassette, the protective black paper is removed from around the film and the film inserted into the cassette with the emulsion side of the film out so that it will receive the roentgen rays on

exposure. The back side of this single emulsion film is of a nonhalation composition. The film is inserted into the cassette by bending the open ends of the black protective paper back to the end of the film. The film is then inserted under the guides and moved into position. The bottom guard is locked, the film guard put in position with the white topped edge out, and returned to the unexposed side of the by-pass.

A thermometer is constantly kept in the developing tank in order to maintain a very close and constant check on the temperature of the developer at all times. The safe light over the work bench is of the Wratten Series Six B. The distance from the safe light to the work bench is 36 inches. At this distance, exposed film could lie on the work bench for a period of twelve minutes before any light fog would be seen on the processed film.

The developing solution is stirred the first thing in the morning and several times throughout the day. In this way none of the unexposed silver nitrates have a chance to settle to the bottom of the developing tank. Water is run continuously into the wash compartments of the tank at the rate of twelve complete changes per hour. All the water entering the wash tanks has been run through the water cooler. This cooler is governed to the mean temperature and pressure of the city water. The water enters the wash tank at a constant temperature of 68° F. The water is left running twenty-four hours a day, six days a week. On Sunday evenings just before the charge of quarters closes the building, he is instructed to start the water cooler. In this way the temperature of the developer and the fixer is maintained at 68° F. for processing the films the next day. This department feels that only through such a procedure can the temperature of the developer and fixer be kept constant.

The developer used is Eastman Kodalk. A close check is kept on the number of 4 by 10 inch, and 14 by 17 inch films processed (one 14 by 17 inch is calculated to be equal to five 4 by 10 inch films). When the combined number of films developed is equal to one thousand 4 by 10 inch films the solutions are discarded. At this time, 10 ballons of fresh developer are prepared and placed in the cleansed developing tank. An extra 5 gallons are prepared at the same time to be used as replenisher. A fresh 15 gallon tank of fixer is made at this time and placed in the cleansed fixing tank.

Films are developed exactly according to time and temperature technique only. The films after developing are allowed to remain in the fixing bath for a period of fifteen minutes. They are then transferred to the wash tank, and are washed for a period of thirty minutes. The films are then placed in the dryer.

No films are read at this induction station in a wet, damp or sticky condition.

By the time the roentgenologist is ready to read the roentgenograms, all the films have been processed, dried and placed in x-ray numerical order. In this manner the roentgenologist can read the man's name and x-ray number at a reasonable rate of speed. Two men work with the roentgenologist in the reading room. One man records the findings opposite the man's name on a special check list, while the other man files the roentgenogram the roentgenologist has just read. Envelopes are prepared ahead of time. These envelopes bear the man's name, home address, daily tag number, x-ray number, the words "essentially negative," the man's Army serial number, Medical Section, New Haven Armed Forces Induction District and are ready for transmittal to the Veteran's Administration in Washington, D. C.

WAR DEPARTMENT

John Doe L.B. III X-100000
18 Osborn St., New Haven, Conn. 172
Official Business

MEDICAL SECTION
New Haven Armed Forces Ind. Dist.
Orange Street Armory
Essentially Negative New Haven, Conn.

ASN 703295

Any individual whose roentgenogram revealed any questionable evidence of a

pathological condition of the chest is "called back" for a 14 by 17 inch stereoroentgenogram of his chest. If after further study of the 4 by 10 inch film with the 14 by 17 inch film, any pathological process is revealed, the roentgenologist interviews the man in the film reading room, obtains a history and records the case on our standard forms—with complete roentgenographic findings.

INTERPRETATION OF CHEST ROENTGENOGRAM

Date 17 December 1943

NAME John Doe X-ray #100,000

ADDRESS 18 Osborn St., New Haven, Conn. Age 20

FAMILY PHYSICIAN Dr. Richard Roe

ADDRESS 19 Filbert Street, New Haven, Conn. Sex M

Race W

General Characteristics of Film: Satisfactory

(Bony thorax, extrathoracic, mediastinum, diaphragm, right lung, left lung, impressions.)

CHARLES C. VERSTANDIG, M.D.

Impressions only are given in this interpretation of shadows seen on the roentgenogram. A diagnosis should be made only after all factors have been taken into consideration. A clinical diagnosis of tuberculosis is reportable to the Health Officer.

The man is then advised to consult his family physician for further study. He is also told that a copy of the report is sent to the State Tuberculosis Commission and that this Commission will get in touch with him, as well as his family physician, in the very near future.

The roentgenograms of men with a pathological condition in the chest are distributed as follows: one of the 14 by 17 inch films is sent to the State Selective Service Commission, the other with the 4 by 10 inch film accompanied by the roentgenologist's report is sent to the State Tuberculosis Commission.

Once a week the 4 by 10 inch cassettes as well as the 14 by 17 inch cassettes are cleaned. Minor repairs are made at this time, if necessary. Each evening before the dark room "team" is through, all the developing hangers that have been used during the day are thoroughly washed, dried and hung ready for use the next day.

We have found that by these standard rules and routines we are able to obtain a highly satisfactory type of photoroentgenogram.

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Twenty-eighth Annual Meeting: 1944, to be announced.

EDITORIALS

JOINT MEETING OF THE AMERICAN ROENTGEN RAY SOCIETY AND THE RADIOLOGICAL SOCIETY OF NORTH AMERICA

FROM September 24 to 29, 1944, the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America was held at the Palmer House in Chicago, Illinois. There had been skeptics who doubted the wisdom and even the possibility of holding a satisfactory war time meeting in the face of such difficulties as limited food supplies, overtaxed transportation facilities and crowded hotel accommodations. The resulting session is the best answer to the critics, for the meeting which was brought about by the combined efforts of the various committees, and especially the Coordinating Committee, surpassed the hopes of the most sanguine and stilled the criticisms of the most cynical.

Despite transportation problems, the attendance was large (a registration of over 1,200) and those fortunate enough to attend seemed to be conscious of their privilege and desirous of making the most of the meeting denied them in 1943.

All sessions were well attended, and during intermissions the Scientific and Commercial Exhibits were objects of unusual attention.

The Refresher Courses, held Sunday afternoon and evening and every morning during the week day sessions, were filled to capacity, many of those desiring to attend being turned away. Dr. Warren W. Furey is to be congratulated on the variety of practical subjects and the excellent teaching talent he procured for these invaluable instructional and review courses.

Dr. Sherwood Moore, President of the American Roentgen Ray Society, was in the chair at the first general assembly, introducing Dr. J. J. Moore, President of the Chicago Medical Society, who welcomed members and guests to Chicago in a very generous and appropriate manner. Dr. E. R. Witwer, President of the Radiological Society of North America, and Chairman of the Coordinating Committee, responded with a few well chosen remarks. The scientific part of this program included addresses by Dr. Herman L. Kretschmer, President of the American Medical Association, Colonel B. R. Kirklin, representing Major General Kirk, the Surgeon General of the Army, and Lieutenant Commander Robert K. Arbuckle representing Vice Admiral McIntyre, the Surgeon General of the Navy.

On Tuesday morning, with Dr. Witwer presiding at the general assembly, Dr. Lyell C. Kinney of San Diego, California, was installed as President of the American Roentgen Ray Society.

On Wednesday morning at the general assembly, Dr. E. R. Witwer of Detroit, Michigan, delivered his address as President of the Radiological Society of North America.

All morning assemblies were of general interest with suitable addresses by outstanding medical men. Afternoon sessions were in sections—Diagnosis and Therapy—enabling a choice of attendance at lectures of particular interest to the individual.

In keeping with the times and due to the fact that so many Society members are in Service, a large number of the essayists were members of the Armed Forces, and

their subjects were of special interest for their military application or because they drew largely on military experience for their material.

A highlight of the Joint Meeting was the annual memorial lecture, this year appropriately combined as the Caldwell-Carman Lecture, given by Dr. Lawrence Reynolds, Director of the Department of Radiology, Harper Hospital, Detroit, Michigan. Dr. Reynolds chose for his subject "The History of the Use of the Roentgen Ray in Warfare," and he delineated the salient facts about the development of roentgen apparatus and its early and gradual introduction to warfare until it attained its present high efficiency and universal use, including a discussion of the high voltage equipment invaluable in the inspection of the planes and guns produced in our war plants. Dr. Reynolds interspersed his lecture with lantern slides illustrating the crude equipment of the early days, and added to the scholarly nature of his address by giving the historical and geographic background of the early military campaigns in which roentgen rays were first used, including topographic maps and old photographs of actual scenes. At the conclusion of his lecture, Dr. Reynolds was presented with a testimonial scroll by Dr. Witwer on behalf of the two societies.

To those fortunate enough to be in attendance, the Annual Banquet on Thursday, September 28, was a memorable occasion. Dr. E. L. Jenkinson presided and Dr. Franklyn B. Snyder, President of Northwestern University, was the principal after-dinner speaker. Officers of both societies were presented to the assemblage and Dr. Lewis G. Allen, of Kansas City, was installed as President of the Radiological Society of North America. Dr. Clarence E. Hufford, Chairman of the Committee on Scientific Exhibits, who with his coworkers collected an unusually large and interesting group of exhibits for the session, presented the awards of merit for the exhibits declared most meritworthy by the judges.

The First Award was given to Drs. Eugene P. Pendergrass, John Q. Griffith and Nicholas Padis, Robinette Foundation, Hospital of the University of Pennsylvania, Philadelphia, for their instructive and well presented work on "Pituitary Irradiation Controlled by Biologic Tests." This is an important contribution to radiation therapy, eliminating much of the inaccurate and unpredictable from such treatment.

The Second Award was given to Drs. L. L. Robbins and C. H. Hale, Massachusetts General Hospital, Boston, for their very practical demonstration of variously located atelectases of the lungs. Their exhibit was entitled "The Roentgen Appearance in Collapse of the Lung and its Subdivisions."

The exhibit by Paul S. Henshaw, Ph.D., National Cancer Institute, Bethesda, Maryland, entitled "Radio-leukemia" received the Third Award. It graphically showed the effect of irradiation on blood cells, using an irradiated mouse and a Geiger counter. Every radiologist, no doubt, felt a personal interest in this exhibit with its warning of the possibility of development of leukemia as the result of repeated casual exposure to roentgen rays or radium.

Drs. Samuel G. Henderson and Louise S. Sherman, Elizabeth Steel Magee Hospital, Pittsburgh, earned First Honorable Mention for a beautiful demonstration of the "Roentgen Anatomy of the Skull in the Newborn Infant."

Dr. Robert B. Taft, Charleston, South Carolina, had an interesting exhibit on "Radium Contamination of Film Boxes" which gave him Second Honorable Mention, and should give him heart-felt thanks from harried roentgenologists as well as producers of roentgen films.

Commander Carleton B. Peirce and his group of officers from the Royal Canadian Navy received Third Honorable Mention

for their exhibit on "Arthrography of the Knee," showing interesting conditions revealed by pneumography.

The judges must have had a difficult time in arriving at their decision for most of the exhibits had special attraction because of completeness and timeliness of subject.

Thirty manufacturers expressed their interest in the meeting by being represented in the Commercial Exhibit. Their displays were the finest seen at any radiological meeting, and much of interest and educational value was shown.

The members and guests who attended the Joint Meeting owe a debt of gratitude to the officers and committees for their courage, foresight and tireless industry in overcoming so many difficulties and providing such an enjoyable and profitable session. Thanks also are due to those who took time out of their busy practice to prepare papers and exhibits for the scientific program.

The Palmer House and its personnel also deserve the thanks and gratitude of the Joint Meeting for their efficiency under war time difficulties. Their efforts contributed greatly to the smooth running of all phases of the meeting which will be a memorable one.

E. W. Hall

FREDERICK C. MARTIN
1884-1944

FREDERICK C. MARTIN, Manager of the Medical Division of the Eastman Kodak Company, Rochester, New York, died on August 20, 1944, at the age of fifty-nine, after many months of illness. He was born on November 2, 1884, in Philadelphia, Pennsylvania, where he obtained his education and early business training. He became interested in photography, particularly in the color processes then in use, and in 1914 he associated himself with the Hess-Ives Corporation, a Philadelphia photographic research firm. While with that organization Mr. Martin had the opportunity to become closely acquainted with commercial photography, especially photoengraving. This

knowledge later helped him to maintain high standards of reproduction in the publications of the Kodak Medical Division.

Mr. Martin became associated with the Eastman Kodak Company November 8, 1916, and was first employed in the Photographic Department of the Kodak Research Laboratories at Rochester, New York. During World War I he was an instructor in the Army School of Aerial Photography which was located in Kodak Park. He became increasingly interested in roentgenography and he began a period of work in the X-ray Department of the Kodak Research Laboratories. From there, in 1920, he went to the Sales Department at Kodak Office and was appointed Assistant Manager of the Medical Division a short time afterward. He was made Manager of the Division in November, 1929, a position which he held until his death.

Mr. Martin was unsparing in the employment of his knowledge, understanding and energy, both in directing the work of his sales force and in carrying on his own business contacts. His pleasant personality, keen sense of humor, and helpful guidance in technical matters earned for him the friendship and esteem of radiologists and his colleagues among roentgen-ray equipment manufacturers throughout the country. Continual study made him responsible for many technical developments in the roentgen-ray field, such as improvements in film usefulness, standardization of processing room procedures and design of accessories.

Mr. Martin was a faithful attendant at the various radiological meetings where he was always most welcome both because of his congenial personality and for his many helpful suggestions to radiologists in solving their problems. Mr. Martin's death is a distinct loss to radiology and his place will not be an easy one to fill.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

Items for this section solicited promptly after the events to which they refer.

MEETINGS OF ROENTGEN SOCIETIES*

United States of America

American Roentgen Ray Society
Secretary, Dr. H. Dabney Kerr, University Hospital, Iowa City, Iowa. Annual meeting: 1945, to be announced.

American College of Radiology
Secretary, Mac F. Cahal, 540 N. Michigan Ave., Chicago, Ill.

Section on Radiology, American Medical Association
Secretary, Dr. U. V. Portmann, Cleveland Clinic, Cleveland, Ohio.

Arkansas Radiological Society
Secretary, Dr. J. S. Wilson, Mack Wilson Hospital, Monticello, Ark. Meets every three months and also at time and place of State Medical Association.

Radiological Society of North America
Secretary, Dr. D. S. Childs, 607 Medical Arts Bldg., Syracuse, N. Y. Annual meeting: 1945, to be announced.

Radiological Section, Baltimore Medical Society
Secretary, Dr. Walter L. Kilby, Baltimore. Meets third Tuesday each month, September to May.

Section on Radiology, California Medical Association
Secretary, Dr. Earl R. Miller, University of California Hospital, San Francisco, Calif.

Radiological Section, Connecticut Medical Society
Secretary, Dr. Max Climan, 242 Trumbull St., Hartford, Conn. Meets bi-monthly on second Thursday, at place selected by Secretary. Annual meeting in May.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. H. W. Ackemann, 321 W. State St., Rockford, Ill.

Radiological Section, Los Angeles County Medical Association
Secretary, Dr. Roy W. Johnson, 1407 S. Hope St., Los Angeles, Calif. Meets on second Wednesday of each month at the County Society Building.

Radiological Section, Southern Medical Association
Secretary, Dr. Roy G. Giles, Temple, Texas.

Brooklyn Roentgen Ray Society
Secretary, Dr. Leo Harrington, 880 Ocean Ave., Brooklyn, N.Y. Meets monthly on fourth Tuesday, October to April.

Buffalo Radiological Society
Secretary, Dr. Joseph S. Gian-Francheschi, 610 Niagara St., Buffalo, N. Y. Meets second Monday of each month except during summer months.

Chicago Roentgen Society
Secretary, Dr. F. H. Squire, 1754 W. Congress St., Chicago 12, Ill. Meets second Thursday of each month October to April inclusive at the Palmer House.

Cincinnati Radiological Society
Secretary, Dr. Samuel Brown, 707 Race St., Cincinnati, Ohio. Meets third Tuesday of each month, October to May, inclusive.

Cleveland Radiological Society
Secretary, Dr. D. D. Brannan, 11311 Shaker Blvd., Cleveland 4, Ohio. Meets at 6:30 P.M. at Allerton Hotel on fourth Monday each month, October to April, inclusive.

Dallas-Fort Worth Roentgen Study Club
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meetings held in Dallas on odd months and in Fort Worth on even months, on third Monday, at 7:30 P.M.

Denver Radiological Club
Secretary, Dr. Edward J. Meister, 366 Metropolitan Bldg., Denver, Colo. Meets third Friday of each month at Denver Athletic Club.

Detroit Roentgen Ray and Radium Society
Secretary, Dr. E. R. Witwer, Harper Hospital. Meets monthly on first Thursday from October to May, at Wayne County Medical Society Building.

Florida Radiological Society
Acting Secretary, Dr. Walter A. Weed, 204 Exchange Bldg., Orlando, Fla. Meetings in May and November.

Georgia Radiological Society
Secretary, Dr. James J. Clark, 478 Peachtree St., Atlanta, Ga. Meets in November and at annual meeting of Medical Association of Georgia in the spring.

Radiological Society of Kansas City
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month at a place designated by the president.

Illinois Radiological Society
Secretary, Dr. Wm. DeHollander, St. John's Hospital, Springfield, Ill. Meets three times a year.

Indiana Roentgen Society
Secretary, Dr. H. C. Ochsner, Methodist Hospital, Indianapolis. Meeting held the second Sunday in May annually.

Kentucky Radiological Society
Secretary, Dr. W. C. Martin, 321 W. Broadway, Louisville. Meets annually in Louisville on first Saturday in Apr.

Long Island Radiological Society
Secretary, Dr. Marcus Wiener, 1430-48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:30 P.M.

Louisiana Radiological Society
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

Michigan Association of Roentgenologists
Secretary, Dr. E. M. Shebesta, 1429 David Whitney Bldg., Detroit. Three meetings a year, Fall, Winter, Spring.

Milwaukee Roentgen Ray Society
Secretary, Dr. C. A. H. Fortier, 231 W. Wisconsin Ave., Milwaukee, Wis. Meets monthly on second Monday at University Club.

Minnesota Radiological Society
Secretary, Dr. Annette T. Stenstrom, 1218 Medical Arts Bldg., Minneapolis, Minn. One meeting a year at time of Minnesota State Medical Association.

Nebraska Radiological Society
Secretary, Dr. D. A. Dowell, Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month, at 6 P.M. at either Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. George Levene, Massachusetts Memorial Hospitals, Boston, Mass. Meets monthly on third Friday, Boston Medical Library.

Radiological Society of New Jersey
Secretary, Dr. H. R. Brindle, 501 Grand Ave., Asbury Pk. Meets annually at time and place of State Medical Society. Mid-year meetings at place chosen by president.

New York Roentgen Society
Secretary, Dr. Ramsay Spillman, 115 East 61st St., New York City. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Roentgen Ray Society
Secretary, Dr. Major Fleming, Rocky Mount, N. C. Annual meeting at time and place of State Medical Society. Mid-year scientific meeting at place designated.

* Secretaries of Societies not here listed are requested to send the necessary information to the Editor.

North Dakota Radiological Society
Secretary, Dr. L. A. Nash, St. John's Hospital, Fargo. Meetings held by announcement.

Central New York Roentgen Ray Society
Secretary, Dr. C. F. Potter, 820 S. Crouse Ave., Syracuse. Three meetings a year. January, May, November.

Ohio Radiological Society
Secretary, Dr. Henry Snow, 1061 Reibold Bldg., Dayton, Ohio.
Meets at time and place of annual meeting of Ohio State Medical Association.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. L. E. Wurster, 416 Pine St., Williamsport.

Philadelphia Roentgen Ray Society
Secretary, Dr. R. P. Barden, University Hospital, Meetings first Thursday of each month from October to May inclusive at 8:15 P.M., in Thompson Hall, College of Physicians, 19 S. 22d St.

Pittsburgh Roentgen Society
Secretary, Dr. L. M. J. Freedman, 4800 Friendship Ave. Meets second Wednesday each month, 4:30 P.M., October to June, Pittsburgh Academy of Medicine.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. Murray P. George, Strong Memorial Hospital. Meets monthly on third Monday from October to May, inclusive, 8 P.M. at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary Dr. A.M. Popma, 220 N. First St., Boise, Idaho.

St. Louis Society of Radiologists
Secretary, Dr. E. W. Spinzig, 2646 Potomac, St. Louis, Mo. Meets fourth Wednesday of each month, except June, July, August, and September, at a place designated by the president.

San Diego Roentgen Society
Secretary, Dr. Henry L. Jaffe, Naval Hospital, Balboa Park, San Diego, Calif. Meets monthly on first Wednesday at dinner.

San Francisco Radiological Society
Secretary, Dr. Martha Mottram, 450 Sutter St., San Francisco. Meets monthly on third Thursday at 7:45 P.M., first six months of year at Toland Hall, University of California Hospital, second six months at Lane Hall, Stanford University Hospital.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 P.M., September to May inclusive.

South Carolina X-Ray Society
Secretary, Dr. T. A. Pitts, Baptist Hospital, Columbia, S. C. Meets in Charleston on first Thursday in November, also at the time and place of South Carolina State Medical Association.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, 707 Walnut St., Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. Asa E. Seeds, Baylor Hospital, Dallas, Texas. Next annual meeting, Temple, Texas, January 17, 1945.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7 P.M. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets every Thursday from 4:00–5:00 P.M., Room 301, Service Memorial Institute.

Virginia Radiological Society
Secretary, Dr. E. L. Flanagan, 116 E. Franklin St., Richmond, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. Thomas Carlile, 1115 Terry St., Seattle. Meets fourth Monday each month, October through May, College Club, Seattle.

X-ray Study Club of San Francisco
Secretary, Dr. J. M. Robinson, University of California Hospital. Meets monthly in evening on third Thursday.

Cuba

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Medical Members' meeting held monthly on third Friday at 2:30 P.M. and Ordinary Meeting at same time on following Saturday, October to May, 32 Welbeck St., London, W.1.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets on the third Friday of each month at 4:45 P.M. at the Royal Society of Medicine 1, Wimpole St., London, W. 1.

Faculty of Radiologists
Secretary, Dr. M. H. Jupe, 32 Welbeck St., London, W. 1 England.

Section of Radiology and Medical Electricity, Australasian Medical Congress
Secretary, Dr. H. M. Cutler, 139 Macquarie St., Sydney, New South Wales.

Radiological Section of the Victorian Branch of the British Medical Association
Secretary, Dr. Keith Hallam, St. George's Hospital, K.E.W., Melbourne, E. 4, Victoria, Australia. Meets monthly from March to November inclusive.

Canadian Association of Radiologists
Secretary, Dr. A. D. Irvine, 540 Tegler Bldg., Edmonton, Alberta.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Radiological Section, New Zealand British Medical Association
Secretary, Dr. Colin Anderson, Invercargill, New Zealand. Meets annually.

South America

Sociedad Argentina de Radiologia
Secretary, Dr. Guido Gotta, Buenos Aires, Argentina. Meetings are held monthly.

Continental Europe

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Société Suisse de Radiologie (Schweizerische Röntgen-Gesellschaft)
Secretary for French language, Dr. A. Grosjean La Chaux de Fonds.
Secretary for German language, Dr. Scheurer, Molzgasse Biel. Meets annually in different cities.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banul Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad: USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Leningrad Roentgen Ray Society
Secretaries, Drs. S. G. Simonson and G. A. Gusterin. Meets monthly, first Monday at 8 o'clock, State Institute of Roentgenology and Radiology, Leningrad.

Moscow Roentgen Ray Society
Secretaries, Drs. L. L. Holst, A. W. Ssamygin and S. T. Konobejevsky. Meets monthly, first Monday, 8 P.M.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

MECHANISM OF DEGLUTITION

To the Editor:

In a recent number of this Journal* was published an abstract of an article in which the ability of a man to swallow while standing on his head was ascribed as being due to "suction."

During 1941 we prepared a cinefluorographic film on the mechanism of deglutition. When we came to the part in which we wanted to demonstrate the peristaltic action of the human esophagus, we arranged a stand above the fluorographic machine so that the subject could hang his head and body downward in front of the screen, supported by his legs on top. The fluid to be swallowed was placed in a glass on a low table below the edge of the screen and drawn into the mouth through straws. This was tried by a large number of interns and nurses in addition to the laboratory personnel and some general by-standers. It was found that everyone who tried could do it. Finally two intern-volunteers, who were chosen primarily because of their slight stature and thin chest measurements, were photographed in the act. Figure 2 is a print from the resulting movie.

It was found necessary to use an unusual projection angle in order to get the shadow of the esophagus well away from the spine and the great vessels. In this print, the body is somewhat inclined and the direction of the beam through the body is postero-anterior and right-to-left oblique. The left side of the chest is against the screen. It was found that in carrying the heavy barium mixture upward, the motion of the esophagus was much more than the usual fluoroscopic image would lead anyone to expect and that in any other position tried, some part of the course was obscured.

The man drew the barium mixture into his mouth by extending the rigid jaw structure and withdrawing the tongue to produce a potential space into which atmospheric pressure pushed the fluid. He then reversed the process and, by means of the usual muscular contractions, projected the fluid into the lower end (i.e., normally the upper end) of the esophagus. At this point it formed a bolus which was then carried upward by a peristaltic wave and deposited more or less completely in the stomach. In the case of the man, usually a small amount of the fluid ran back and was picked up by the succeeding wave.

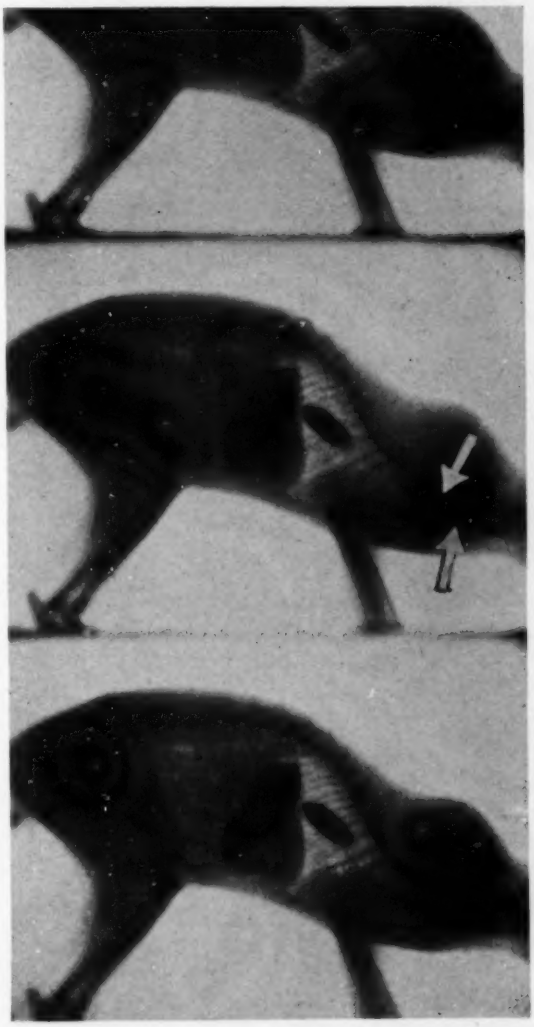

Fig. 1.

Quadrupeds normally drink with the cardiac end of the stomach higher than the mouth. A cat, having had much more prac-

* Robinson, T. A. A note on the mechanism of deglutition. *Brit. J. Radiol.*, 1942, *15*, 209–210. Abs. in Am. J. Roentgenol. & Rad. Therapy, August, 1944, *52*, 230.

tice of course, put on a better demonstration than the man. The cat used no suction whatever, but employed a two-stroke-cycle reciprocating mechanism of the jaw, tongue and throat muscles. The cat threw a large drop of the fluid to the back of his mouth with a quick flip of his tongue and forced

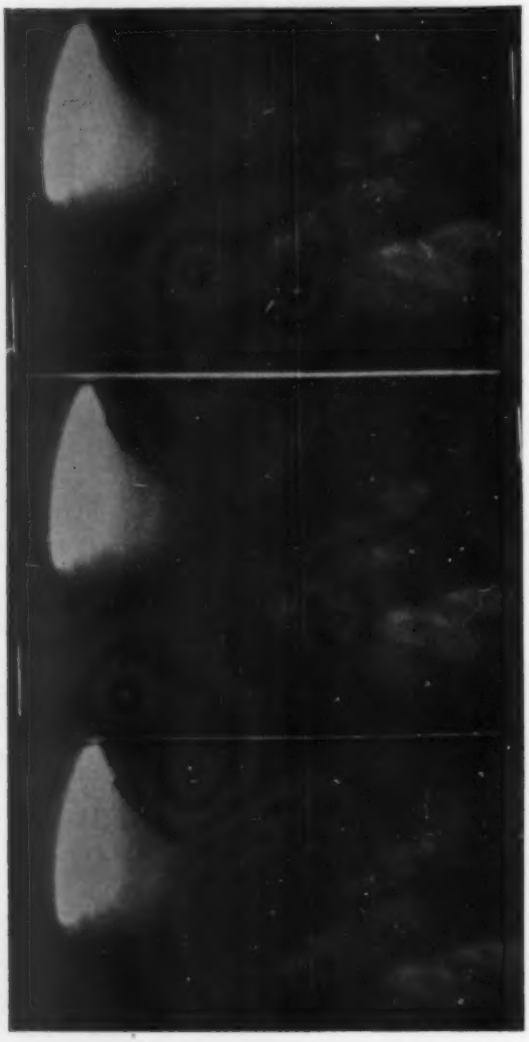

Fig. 2.

it into the lower end of the esophagus by the same swallowing mechanism as the human. This was done very quickly and very rapidly. The drops collected in the lower end of the esophagus which served as reservoir and was partially filled at all times while the animal was drinking. Peristaltic waves originated about midway of this "reservoir" and each carried a large, clear bolus up to the stomach. The rate of travel was quite slow and quite non-uniform; they were timed all the way from five to eight seconds. Usually the wave slowed down, sometimes coming practically to a stop, when the leading end of the bolus encountered the cardiac sphincter, then it would speed up again and the bolus disappear into the stomach. At rare intervals some of the fluid would escape through the wave constriction and run back down the esophagus, in which case it always ran all of the way back to the "reservoir." There never appeared to be more than one wave in motion at a time; this in contrast to the human.

The man finally emptied his esophagus by a series of little peristaltic waves which ran up in quick succession, after he finished swallowing. The cat put a final touch to his meal by raising his head, stretching his neck and giving one last strong gulp, evidently with great satisfaction.

Two prints from the moving picture film are shown. In Figure 1 are to be noted the "reservoir," the clear bolus, and the partially filled stomach. In Figure 2, the esophagus appears partially filled throughout its length, as the waves succeed each other very closely and are not so clear-cut. It is to be noted also that the change from one frame to the next indicates how much faster the waves are travelling.

Department of Radiology
Harper Hospital
Detroit, Mich.

K. E. Corrigan
H. S. Hayden

UROLOGY AWARD

The American Urological Association offers an annual award "not to exceed $500" for an essay (or essays) on the result of some specific clinical or laboratory research in Urology. The amount of the prize is based on the merits of the work presented, and if the Committee on Scientific Research deem none of the offerings worthy,

no award will be made. Competitors shall be limited to residents in urology in recognized hospitals and to urologists who have been in such specific practice for not more than five years. All interested should write the Secretary for full particulars.

The selected essay (or essays) will appear on the program of the forthcoming June meeting of the American Urological Association.

Essays must be in the hands of the Secretary, Dr. Thomas D. Moore, 899 Madison Avenue, Memphis, Tennessee, on or before March 15, 1945.

Miley B. Wesson, *Chairman*
Committee on Scientific Research

DIRECTORY OF MEDICAL SPECIALISTS

The biographic data of the first two editions of the Directory of Medical Specialists included only positions (internships, residencies, or assistantships) held during the course of training of men up to the time of their certification by the American Boards, and hospital and medical school staff positions then currently held.

It is desired to extend these data in the Third Edition to include all formal hospital and medical school appointments, with dates held, even though now resigned, as well as records of all military service including commissions and dates, either in World War I, peace-time in the Reserve forces, or in the present war.

Thus, a chronologically complete sketch of a Diplomate's entire career is to be included in this Third Edition of the Directory.

Membership or fellowship in national or sectional (not local) special societies, and national general societies with offices held, and dates, in any of these, should be reported.

Membership in recognized international medical societies may be included, but honorary or other membership in foreign medical societies should not be reported.

Reference to the Second Edition (1942) of the Directory may be made for lists of medical societies to be included in one's biographic sketch.

Families or secretaries of men absent in military service are asked to complete or correct previous listings or new forms now being mailed to those eligible for inclusion in the Directory. Only those certified by an official American Board can be included, and there is no charge for this listing.

The foregoing notice is published in response to many inquiries, to assist those certified by the American Board who are now engaged in correcting their previous listings, or preparing new sketches for the Third Edition of the Directory to be published early in 1945.

Communications should be addressed to the Directory of Medical Specialists, 919 North Michigan Avenue, Chicago 11, Illinois.

COMMERCIAL EXHIBIT

The Commercial Exhibit, which was a prominent part of the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America, held at the Palmer House, Chicago, Illinois, September 24–29, 1944, was an outstanding one both from the point of view of the number of exhibits and general attractiveness of the displays, as well as the various types of equipment shown. Fifty-eight booths were occupied by thirty exhibitors. The exhibits shown included many types of roentgen-ray equipment, and drugs and accessories used by radiologists, radium supplies, and books and journals of interest to radiologists. Intermissions were arranged each day of the meeting to give all those in attendance an opportunity to view the exhibits. At these times the exhibit floor was crowded but at many other times during the day the large number of radiologists seen in the various booths in earnest conversation with the manufacturers' representatives was proof that radiologists welcomed this opportunity for personal contact with the manufacturers after such a lack for two years due to the cancellation of the meetings of both Societies in 1943.

Those having to do with the arrangements of the Joint Meeting of the American Roentgen Ray Society and the Radiological Society are most appreciative of the interest shown by the manufacturers and herewith extend their thanks to those who participated and who added so greatly to the success of the meeting.

The following were represented in the Commercial Exhibit: *Ansco*, Binghamton, New York; *Buck X-Ograph Company*, St. Louis, Missouri; *Canadian Radium & Uranium Corporation*, New York; *E. I. du Pont de Nemours & Company*, Wilmington, Delaware; *Eastman Kodak Company*, Rochester, New York, *Eureka X-Ray Corporation*, Chicago, Illinois; *General Electric X-Ray Corporation*, Chicago, Illinois; *Kelley-Koett Manufacturing Company*, Covington, Kentucky; *Lea & Febiger*, Philadelphia, Pennsylvania; *Liebel-Flarsheim Company*, Cincinnati, Ohio; *Machlett Laboratories*, Springdale, Connecticut; *F. Mattern Manufacturing Company*, Chicago, Illinois; *Medical Bureau*, Chicago, Illinois; *National Synthetics*, New York, New York; *Newman X-Ray Corporation*, Aurora, Illinois; *North American Philips Company*, New York, New York; *Pako Corporation*, Minneapolis, Minnesota; *Picker X-Ray Corporation*, New York, New York; *Powers X-Ray Products Company*, Glen Cove, New York; *Radiology*, Detroit, Michigan; *Radium Chemical Company*, New York, New York; *Schering Corporation*, Bloomfield, New Jersey; *Sola Electric Company*, Chicago, Illinois: *Standard X-Ray Company*, Chicago, Illinois; *Charles C Thomas*, Springfield, Illinois; *Victoreen Instrument Company*, Cleveland, Ohio; *Westinghouse Electric & Manufacturing Company*, Pittsburgh, Pennsylvania, *Winthrop Chemical Company*, New York, New York; *Wolf X-Ray Products*, New Yoık, New York; *Year Book Publishers*, Chicago, Illinois.

NEW OFFICERS

The following officers of the American Roentgen Ray Society were elected for 1944–1945 at an executive session of the Society held during the Joint Meeting of the American Roentgen Ray Society and the Radiological Society of North America held at the Palmer House, Chicago, Illinois, September 24–29, 1944: *President-elect:* Dr. Ross Golden, New York; *First Vice-President:* Dr. Raymond C. Beeler, Indianapolis; *Second Vice-President:* Commander Harold W. Jacox, M.C., U.S.N.R.; *Secretary:* Dr. H. Dabney Kerr (re-elected), Iowa City, Iowa; *Treasurer:* Dr. J. B. Edwards (re-elected), Leonia, N. J.; *Historian:* Dr. Ramsay Spillman (re-elected), New York; *Chairman of Executive Council:* Dr. J. C. Dickinson, Tampa, Florida; *New Member of the Executive Council:* Dr. Harry M. Weber, Rochester, Minnesota. Dr. Lyell C. Kinney, San Diego, assumed the office of *President.*

Vol. 52, No. 5

DEPARTMENT OF TECHNIQUE

Department Editor: Robert B. Taft, M.D., B.S., M.A., 103 Rutledge Ave.
Charleston, S. C.

SIMPLE METHOD FOR STUDY OF THE COLON IN THE PRESENCE OF A COLOSTOMY

By LIEUTENANT COLONEL ROBERT C. PENDERGRASS
Medical Corps, Army of the United States
and
CAPTAIN FREDERICK W. COOPER, JR.
Medical Corps, Army of the United States

THE generally accepted therapy of performing a colostomy for wounds of the large bowel has brought an increasing number of these cases under observation. The evaluation of the condition of the lower segment of bowel by roentgenographic and sigmoidoscopic examination is difficult unless the stoma of the colostomy is effectively plugged. With injection of barium, the rectum and colon cannot be well distended due to rapid escape of the enema through the colostomy. Not only is unsatisfactory visualization obtained but escape of the barium upon the abdominal wall may mask the outline of the colon. Soiling of the abdominal wall, dressings and roentgen table usually results. Similarly, if the stoma is allowed to remain open, the distal portion of the bowel cannot be distended with air to facilitate sigmoidoscopy.

Rubber bulbs, such as those used in Asepto syringes, may be obtained in a variety of sizes. The neck of the bulb is inserted into the colostomy stoma and the bulb strapped down firmly with adhesive prior to roentgenographic or sigmoidoscopic examination.

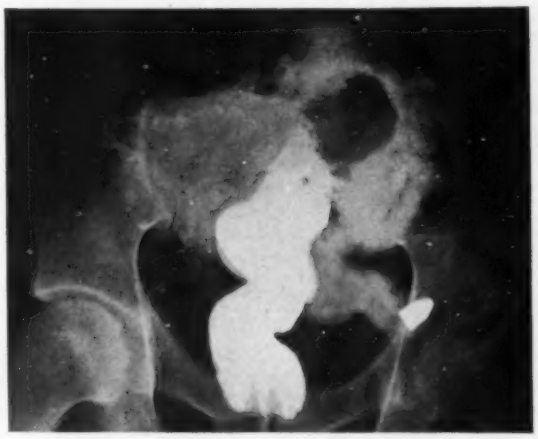

Fig. 1. Barium enema spilled over abdominal wall. Colostomy open.

Fig. 2. Distal colon well filled. Colostomy plugged.

Figure 1 shows spilling of barium over the abdominal wall without use of the colostomy plug. Figure 2, same patient, shows effective plugging of the colostomy opening by the rubber bulb and a well-filled distal colon. The bullet which perforated the lower bowel is seen overlying the left acetabulum.

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ABSTRACTS OF ROENTGEN AND RADIUM LITERATURE

ROENTGEN DIAGNOSIS

HEAD

List, Carl Felix, Osteochondromas arising from the base of the skull. *Surg., Gynec. & Obst.*, April, 1943, *76*, 480–492.

Intracranial tumors of cartilaginous structure are among the most unusual types of neoplasm encountered by the neurologic surgeon. The osteochondromas arising from the base of the skull exhibit a characteristic anatomical and clinical picture. In view of the rare occurrence of the basal osteochondroma as many observations as possible were utilized in this study. The illustrative case histories which are presented are divided into two groups: (1) primarily intracranial osteochondromas, arising from the sphenoid bone (5 cases), and (2) primarily extracranial osteochondromas of the ethmoidal or sphenoidal region with secondary intracranial extension (2 cases).

Anatomical and Pathogenetic Considerations.

1. The base of the skull is a preferential location of osteochondromas.
2. The sphenoid and ethmoid are preferential sites of osteochondromas.
3. These lesions develop apparently from cartilaginous rests of the primordial cranium.
4. It is interesting that chordomas are found in a location similar to that of osteochondromas, viz., at the junction of the basisphenoid with the occiput.

Clinical and Diagnostic Considerations.

1. Incidence and duration of symptoms. These neoplasms usually become clinically manifest in young adults, between the ages of twenty and thirty. Their rate of growth is slow so a clinical course over ten or even twenty years is not unusual.
2. Neurologic symptomatology. The intracranial osteochondroma of the sphenoid produces a characteristic clinical syndrome. As a result of the paraseller location of the lesion, the structures in the wall of the cavernous sinus are affected at an early stage. Primarily extracranial osteochondromas of the ethmoidal or sphenoidal regions produce neurologic signs only in the later phases of the disease.
3. Roentgenographic signs. The presence of basal osteochondromas is revealed by localized erosion of bone combined with dense calcifications in the tumor. Intracranial sphenoidal osteochondromas produce more or less marked parasellar erosion. Ethmoidal osteochondromas may destroy ethmoidal bones, the floor of the anterior fossa, and the medial wall of the orbit. Calcifications in osteochondromas are either arranged in coarse flakes or they may be so dense as to simulate cancellous bone thus outlining the entire tumor mass.
4. Differential diagnosis: (1) aneurysm of the internal carotid artery; (2) parasellar meningiomas; (3) craniopharyngiomas; (4) chordomas.

Treatment and Prognosis. Since osteochondromas do not respond to irradiation, surgical treatment is the only promising form of therapy. Since most intracranial osteochondromas must be removed piecemeal, their extirpation may be incomplete and hence a recurrence is likely to develop eventually. The postoperative period of survival may be a long one unless the neoplasm has sarcomatous propensities.—*Mary Frances Vastine.*

Hawes, Lloyd E., and Meade, Sedgwick. Posterior displacement of the calcified pineal in subtentorial brain tumors. *Radiology*, April, 1943, *40*, 367–370.

Generally displacement of the calcified pineal gland can be relied on in the localization of brain tumor. If the gland is displaced upward the tumor is beneath it, etc. But the authors have seen 3 cases in which the patients had subtentorial (posterior fossa) tumors but the pineal gland was shifted backward. These cases are described and illustrated with a roentgenogram and a diagram of the ventricular system showing the probable cause of the paradoxical displacement. It is due to an internal hydrocephalus caused by obstruction of the outflow of the spinal fluid through the aqueduct. This results

in distention of the third ventricle which pushes the pineal gland backward.—*Audrey G. Morgan.*

Burrows, Harold, Cave, A. J. E., and Parbury, K. Radiographical comparison of the pituitary fossa in male and female whites and Negroes. *Brit. J. Radiol.*, March. 1943, *16*, 87–89.

A roentgenological study of 100 pituitary fossae was made under identical conditions so that the results were comparable. The outlines of the fossae in the median sagittal plane were obtained. Fifty of the skulls were from African Negroes from known localities and 50 were skulls of white persons from an old London cemetery. Tables giving details of the results and silhouettes of white and black, male and female fossae are given. The male fossa was found to be larger than the female; in an examination of various animal species the reverse was found to be true. The fossa was larger in the Europeans than in the Africans. There were great individual variations in the size and shape of the fossae. This is probably due to anthropological and racial factors and a further study should be made of the subject.—*Audrey G. Morgan.*

Griffin, Ernest P., Gianturco, Cesare, and Goldberg, Solomon. A stereoscopic method for the localization of intraorbital foreign bodies. *Radiology*, April, 1943, *40*, 371–374.

The usual methods of localization of foreign bodies in the eye are satisfactory in the hands of experts but complicated and difficult for roentgenologists who do not have much practice. A simple method for localizing such foreign bodies is described which can be used by any roentgenologist. The apparatus used is a localizer and a roentgen visible artificial eye. They are described and illustrated. The localizer consists of a base with a vertical mast to which the artificial eye can be fixed. The patient lies prone on the table with his chin slightly raised by a small pillow and a film of the injured eye is made. The patient then slides down from the table and the artificial eye placed in the position of the injured eye. Two stereoscopic films are then taken with low voltage. This gives two stereoscopic films of the orbit and foreign body on which the stereoscopic shadow of the artificial eye will also be cast. After processing, the films are placed in the stereoscope and the position of the foreign body determined by direct visual observation.

The artificial eye is made for the average size of the human eyeball; as this varies little the method is very accurate except that caution should be exercised in examining the eyes of children and in conditions which are known to cause changes in the axial length of the eye. A necessary condition to the successful use of the method is the possession of good stereoscopic vision by the roentgenologist and ophthalmologist.—*Audrey G. Morgan.*

NECK AND CHEST

Robinson, David W., and Harless, Morris. Papillary cystadenoma lymphomatosum of the parotid gland. *Surg., Gynec. & Obst.*, April, 1943, *76*, 449–452.

The authors report 4 cases of papillary cystadenoma lymphomatosum (adenolymphoma or onkocytoma) of the parotid gland, making a total of 71 which have been described in the literature.

This tumor is a well encapsulated structure which occurs in salivary tissue, usually the parotid gland. It has a firm fibrous capsule. The nodular mass is round, oval, coarsely lobulated, or bosselated and is moderately firm but cuts with ease, revealing a cut surface smooth or finely granular with numerous small cystic spaces.

There are multiple theories as to the origin of this tumor. Many consider that the cyst is of branchiogenic origin. Another popular belief is that the lymphoid tissue of the preauricular node blends with a parotid lobule, the resulting mixture being separate from the parotid itself.

Papillary cystadenoma lymphomatosum occurs chiefly in men of the fifth and sixth decades. The tumor involves most often the lower pole of the parotid, is slow growing, and usually painless. It is easy to remove. Recurrence is rare and radiation therapy is of no value.—*Mary Frances Vastine.*

Haight, Cameron, and Towsley, Harry A. Congenital atresia of the esophagus with tracheoesophageal fistula. *Surg., Gynec. & Obst.*, June, 1943, *76*, 672–688.

The surgically ideal plan for the correction of congenital atresia of the esophagus with tracheo-esophageal fistula is a reconstruction of the continuity of the esophagus by an extrapleural ligation of the fistula and an end-to-end

anastomosis of the esophageal segments. The first successful case of reconstruction of the esophagus by this plan is presented. The factors pertaining to operative correction of the anomaly and experiences in a series of 15 cases are discussed.

Roentgenographic Observations concerning Operability.

1. A liquid radiopaque material is used to determine the level of obstruction of the upper esophageal segment. Iodized oil should be employed instead of a barium suspension as the barium may cause serious pulmonary complications if it gains entrance into the bronchi.

2. The oil is administered under roentgenoscopic control as it is advisable to limit the amount so that it will not overflow into the trachea.

3. At the conclusion of the examination, the retained oil in the upper esophageal segment is aspirated through a catheter.

4. The blind end of the dilated upper esophageal segment is usually found at a level between the first and third dorsal vertebrae. As seen fluoroscopically, the upper esophageal segment is not a fixed structure but undergoes a vertical excursion during respiration.

5. The presence of air in the stomach is indicative of a communication between the trachea and the lower esophageal segment. Although the failure to visualize air in the stomach suggests the absence of a tracheoesophageal fistula, this fact is not necessarily true.—*Mary Frances Vastine.*

MISCELLANEOUS

Paterson, Edith. A comparison of the action of X and gamma rays on fibroblasts. Part II. *Brit. J. Radiol.*, Oct., 1942, *15*, 302–306.

Previous work on this problem has shown that when fibroblast cultures were irradiated on glass coverslips there was no qualitative difference in the action of roentgen and gamma rays. There was a quantitative difference. Roentgen rays were found to be more lethal than gamma rays. This article deals with experiments made to determine whether this difference was due to the atomic weight of the silicon in the glass coverslips. Tests were made with coverslips of heavy materials (gold, lead, glass) and light materials (polystyrene derivatives, paraffin). It was found that on all the heavy materials the action of roentgen rays was more lethal than that of gamma rays but that there was no significant difference in the action of the two kinds of rays on the light materials. It would seem therefore that the action of roentgen rays is influenced by the atomic weight of the material in immediate contact with the cells and that this difference is due to the fact that the heavier substances have a greater secondary emission of electrons.—*Audrey G. Morgan.*

Goodrich, James P. Experimental modification of radiosensitivity of embryonic cells. *Radiology*, Feb., 1943, *40*, 179–187.

Experiments in modifying the radiosensitivity of the eggs of the grasshopper by temperature and dehydration were made at the State University of Iowa, Iowa City. The method of the experiments is described and graphs given showing the details of the results.

These eggs when kept at a constant temperature of 25° C. develop for approximately twenty-one days (prediapause period) at the end of which time they enter a period of developmental block (diapause). If they are then placed at a low temperature (10° C.) for two to three months, on return to a temperature of 25° C. they will undergo further development (postdiapause) and hatch about the eighteenth day. The effect of low temperature was to decrease sensitivity before the third day of prediapause development and to increase it during the remainder of prediapause and the first two days of postdiapause. Dehydration caused an increase in sensitivity before the fifth day of prediapause and a decrease during the remainder of prediapause and on the second day postdiapause.

So far as is known the only common effects of low temperature and dehydration are inhibition of development and reduction in rate of oxygen consumption. These effects are evidently due to a specific action of temperature and dehydration on the cells and it is obvious from the different effects of the two agents that they do not act in the same way. It is possible that low temperature changes the oxidative mechanisms while dehydration may cause changes in the osmotic relations of the cells to the fluids in which they are bathed.

The present experiments show that radiosensitivity of cells may be changed in opposite directions by the same agent at different stages of their development. Further experiments along this line should yield greater understand-

ing of the processes involved in the radiosensitiveness of cells.—*Audrey G. Morgan.*

Gray, L. H., and Read, John. The effect of ionizing radiations on the broad bean root. Part iv. The lethal effect of alpha radiations. *Brit. J. Radiol.*, Nov., 1942, *15*, 320–336.

This is a continuation of a series of investigations of the effect of different kinds of radiation on the broad bean root. The method of experiment is described and the mathematical formulae used in the calculations given, together with graphs and tables showing the details of the results.

The bean roots were immersed in water containing dissolved radon. Two minutes after immersion half the equilibrium value is reached. At equilibrium the concentration of radon in the bean root is the same as that in the surrounding solution. The radon atoms show a marked tendency to accumulate on the surface of the root.

It was found that alpha radiation is about as effective as neutron radiation in killing the broad bean root and about 9 times as effective as gamma radiation.—*Audrey G. Morgan.*

Bisgard, J. Dewey, Hunt, Howard B., Neely, Orvis A., and Scott, Paul. Experimental studies of the mechanism of action of x-ray therapy upon infection. *Radiology*, Dec., 1942, *39*, 691–696.

The authors report experiments on rabbits which show that roentgen irradiation brings about a large reduction in the mortality from toxemia to bacterial origin and that this effect is apparently produced by the liberation of an antitoxic factor. Rabbits were infected with *Escherichia coli* of low virulence so that large doses had to be given. Irradiation after inoculation had no effect, as all the animals died within five hours as did the controls. But when irradiation was given at intervals before inoculation varying from sixteen weeks to twenty-four hours it was found that a considerable degree of protection against an otherwise lethal culture was provided. The protective factor was present in twenty-four hours, reached its maximum at forty-eight hours and had completely disappeared in seven days as there were no survivors among the animals irradiated more than seven days before inoculation.

Injection of peritoneal fluid from the irradiated animals into other rabbits protected them from peritonitis and the blood serum also had this protective action, indicating that the antitoxic factor resulting from irradiation was present in the blood. It may be that protective substances are liberated by breaking down of leukocytes.

The cultures used contained a lethal dose of toxin at the time of injection so that the production of further toxin by growth of the bacteria in the peritoneal cavity was not necessary to cause death. This explains the failure of sulfa drugs in these cases as they are only bacteriostatic agents.

In the discussion Dr. Kelly said that he hoped the work of Dr. Bisgard would reduce the use of extensive debridement and amputation during the acute toxic stage of gas gangrene and give place to the use of roentgen treatment. It is the toxemia that kills and not the local disease. As roentgen rays affect toxemia and the sulfa drugs do not it is evident that the former is to be preferred.

Dr. Lockwood disagreed with the conclusion that this work proved the value of the routine use of roentgen therapy in the treatment of established infections. He said Dr. Bisgard's experimental lesions were quite different from an established invasive infection.—*Audrey G. Morgan.*

Evans, T. C., Slaughter, J. C., Little, E. P., and Failla, G. Influence of the medium on radiation injury of sperm. *Radiology*, Dec., 1942, *39*, 663–680.

Experiments in the irradiation of sperm of the sea urchin (*Arbacia punctata*) and the marine worm *Nereis* are described and tables and graphs given showing the influence of dosage, time and the medium on the injury done to the sperm. As the dosage of radiation is increased fewer sperm in a suspension are capable of fertilizing eggs. This change takes place immediately after irradiation. Also with the lapse of time the number of sperm capable of fertilizing eggs decreases. Also sperm irradiated in the seminal fluid are very resistant to irradiation while with increasing dilution with sea water the radiosensitiveness increases, though it has not been proved that the increase in radiosensitiveness is proportional to the amount of dilution.

It was found that when *Nereis* sperm and *Arabacia* sperm were mixed each seemed to afford a certain degree of protection to the other

against the action of irradiation. Protection was also afforded by the addition of "egg water," the supernatant fluid from the jelly surrounding the *Arbacia* egg; also by egg albumin, gelatine, gum arabic, glycyl-glycine and glycine.

Both the effect of the dilution and the protective action of these substances may be explained on the assumption that irradiation acts indirectly on the sperm through the influence of activated water molecules. The protective substances protect by deflecting the action of these activated water molecules from the sperm to the substances in question. Experiments seemed to show that the hydrogen peroxide produced in irradiated water had little effect on the inhibition of the fertilizing capacity of the sperm. But another effect of irradiation, namely the delay in cleavage time of the eggs fertilized with the irradiated sperm seems to be caused directly by the action of the irradiation on the sperm. Obviously, therefore, it makes a difference in considering damage caused by radiation what effect of the radiation is taken as a measure of the damage.—*Audrey G. Morgan.*

Rigos, Frank J. Roentgenologic irradiation in acute peritonitis and its effect on the cells of the normal peritoneal fluid in guinea-pigs. *Radiology*, Dec., 1942, *39*, 681–690.

In the experiments described in this article peritonitis was induced in guinea pigs by the introduction of colon bacilli or non-hemolytic streptococci. The animals were then treated by irradiation with the following factors: 100 kv., 5 ma., 2 mm. aluminum filter, 20 inches (51 cm.) distance, portal 10×7 cm., air dose 15 r per minute, half-value layer 3 mm. aluminum. Various doses were given. It was found that doses of less than 100 r had little effect on the total cell count of the peritoneal fluid but that they did cause a relative increase in the percentage of macrophages and lymphocytes. Doses of 100 r or more caused an increase in the total cell count. Doses of 200 r or more caused a decrease in the total count with a relative increase in the percentage of macrophages. The macrophage as well as the heterophilic leukocyte is capable of phagocytizing bacteria. It would seem that macrophages appear not as a response to bacterial invasion per se but rather as a result of the action of the heterophils which are the body's first line of defense against invading bacteria.

In these experiments doses of from 50 to 100 r had an irritant effect on the peritoneal fluid; doses of less than 50 r did not have any apparent effect on the cell count, and doses of more than 100 r had an immediate destructive action. Therefore it would appear that doses of 50 to 100 r with their irritant action on the peritoneal fluid may be of value in the treatment of peritonitis in the guinea pig.—*Audrey G. Morgan.*

Mayneord, W. V. What may we expect from physics? *Brit. J. Radiol.*, Oct., 1942, *15*, 286–288.

Closer collaboration between radiologist and physicist is to be hoped for and expected in the future. Generally the physicist is supposed to be concerned chiefly with therapeutic radiology but his collaboration in diagnostic radiology is just as important. And entirely beyond the practical problems of diagnosis and treatment he should be concerned with fundamental biological knowledge rather than mere technical advancement.

There should be a full-time physicist on the staff of every center of diagnostic and therapeutic radiology. He should work side by side with the radiologist in the clinic and become acquainted with the actual bedside problems of the latter. There is a great deal of routine work to be done but the young physicist should have about half his time for study and research, otherwise he will be discouraged from joining the radiological staff but will prefer working in the university. He should also do some teaching work and help to bring the student into contact with the field of physics applied to medicine. At present there is too little contact between academic physics and radiological departments and the staff physicist should broaden and deepen the contact and understanding between them. Doubtless there will be great advances in the future in both technical accomplishment and fundamental biological knowledge brought about by closer collaboration of physicist and radiologist.—*Audrey G. Morgan.*

Farmer, F. T. Considerations in the measurement of x rays for deep therapy. *Brit. J. Radiol.*, July, 1942, *15*, 203–208.

All the methods of measurement discussed in this article depend on the ionization of air by roentgen rays and indicate the dosage in roentgens. The mekapion or Hammer type of

dosimeter has proved of practical value but in applying this instrument to the measurement of the skin dose there is a small space between the skin of the patient and the center of the chamber. This separation, which varies with the manner of applying the instrument, causes some inaccuracy in the measurement. Tube output calibration is reliable if the output of the tube remains constant but tube output may vary considerably in the course of a few minutes and in that case dosage determination by this method becomes unreliable. A fixed chamber integrating dosimeter is described, by the use of which the inaccuracies of the two methods mentioned above may be avoided. The chamber is fixed in the output aperture of the tube. There is an integrating mechanism similar to that of the mekapion on the operator's desk so it is not necessary to place an instrument at the base of the applicator. This arrangement has been found satisfactory as far as physical performance is concerned but its clinical usefulness will have to be tested further.—*Audrey G. Morgan.*

Koch, H. W., Kerst, D. W., and Morrison, P. Experimental depth dose for 5, 10, 15 and 20-million-volt x-rays. *Radiology*, Feb., 1943, *40*, 120–127.

This is a technical discussion of the experimental depth dose for 5, 10, 15 and 20 million volt roentgen rays illustrated with curves showing the experimental results. It is particularly concerned with the 20 million volt electron beam now produced by the University of Illinois betatron. The best way to use the betatron in treatment would be to send the original electrons, accelerated in the vacuum tube, directly into the patient. At 20 million volts they will penetrate 10 cm. and no farther so that no damage is done to the back of the patient. Though a sufficiently intense beam of electrons now comes from the betatron it is not yet in a good enough state of collimation or control for practical use.

The chief characteristics of the high energy depth dose curves are: that the point of maximum dose is as deep as 3 or 4 cm. below the surface of the phantom and that this maximum can be several times greater than the surface dose. Roentgen rays in this energy range, therefore, will pass not only through the skin but also through the subcutaneous fat without causing much damage while a larger dose will act on the deeper tissues. The region to be treated can be placed near the point of maximum intensity of ionization by compression of the patient's body and cross-fire will be less important.—*Audrey G. Morgan.*

Craggs, J. D., and Smee, J. F. Geiger-Müller counters. *Brit. J. Radiol.*, Aug., 1942, *15*, 228–232.

This is a technical description of the properties and uses of Geiger-Müller tube counters, illustrated with tables and curves. The technique of making and using the counters is discussed only briefly as many other articles have been written on the subject but the counting mechanism and technique of operation are given in detail. There is some error in the counts caused by the limited resolving power of the Geiger-Müller counter and associated circuits. —*Audrey G. Morgan.*

Kerst, D. W. The betatron. *Radiology*, Feb., 1943, *40*, 115–119.

The word betatron means an agency for producing high energy electrons and it has been applied to a magnetic induction accelerator which has been constructed at the University of Illinois. It is probable that the most useful application of the betatron will be the production of high-speed electrons or beta rays.

This apparatus introduces a new method of electron acceleration. Energy is transferred to the electrons by the accelerating action of a time-varying magnetic field. As the betatron is a powerful magnet between the poles of which the electrons circulate in essentially one plane, it looks something like a small cyclotron but it can accelerate particles whose velocity is very nearly as great as that of light, while the cyclotron can accelerate only much heavier particles with a much lower velocity.

Diagrams of the betatron are given and its action described in detail. While the 20 million volt apparatus already constructed at the University of Illinois will probably prove useful in therapy the 100 million volt apparatus that has been designed will probably be used in certain cosmic ray work being carried on in the laboratory.—*Audrey G. Morgan.*